COMMENT DRAFT

Minimum Design Standards For Community Water Systems

Revised ____9/09/2010_____________

Comment Deadline __01/01/2011________________

More information can be found at http://dnr.mo.gov/env/wpp/pdwb/permits.htm

Please send written comments to:

Missouri Department of Natural Resources
Public Drinking Water Branch
1101 Riverside Drive
P.O. Box 176
Jefferson City, Missouri 65102-0176
Attn: Permits and Engineering Design Guide Revisions

Or email us at: PDW.Permits@dnr.mo.gov

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DEFINITION OF TERMS

The following is a list of terms used throughout this document and the definition of each.

Average Day Demand-- The amount of water used in an average day, calculated by dividing the total annual water production by the number of days in the year.

Comprehensive Performance Evaluation (CPE) -- A systematic review and analysis of a water treatment plant's performance without major capital improvements. It is the first part of a composite correction program.

Continuing Operating Authority -- The permanent organization, entity or person identified on the permit to dispense water that is responsible for the management, operation, replacement, maintenance and modernization of the public water system in compliance with the Missouri Safe Drinking Water Law and Regulations (see 10 CSR 60-3.020).

Design Instantaneous Peak Flow -- The flow rate measured at the instant the maximum demand is occurring in a water system. It is calculated by multiplying the cross-sectional area of the water pipe by the velocity of the water at any one instant.

Design Average Day Demand -- The anticipated amount of water used in an average day. This is calculated by dividing the anticipated total annual water production by the number of days in the year.

Design Maximum Day's Demand -- The anticipated amount of water needed to satisfy the day of highest water usage. Typically, this is 150% of the Average Day Demand.

Design Period -- The span of time any proposed water system or water system component will be utilized.

Diurnal Flow Pattern – This is a plot of water demand versus time for a 24-hour period. The curve depicts a typical period of time and is used to simulate the daily operation of the network, especially the cycling of system storage.

Fire Protection – This is defined as the ability to provide water through a distribution system for fighting fires in addition to meeting the normal demands for water usage.

Historical Data -- Actual records of past water production, consumption and other operational information.

Maximum Day Demand --The amount of water needed to satisfy the day of highest water usage. Typically, this is 150% of the Average Day Demand.

Maximum Flow -- The greatest amount of water demanded within a specified time period.

Maximum Hour Demand -- The amount of water needed to satisfy the highest flow rate in a water system occurring for one-hour duration.

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Peak Demand -- The maximum momentary load, expressed as a rate, placed on a water treatment plant, distribution system, or pumping station. It is usually the maximum average load in one hour or less, but may be specified as instantaneous or for some other short time period.

Peak Flow -- See: Maximum flow.

Period of Record – This is the time span covered by a particular set of data.

GLOSSARY

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CFR	Code of Federal Regulations
COA	Continuing Operating Authority
CPE	Comprehensive Performance Evaluation
CSR	Code of State Regulations
FAA	Federal Aviation Administration
GAC	Granular Activated Carbon
ISO	Insurance Services Office
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutants Discharge Elimination System
NSF	National Sanitation Foundation
NSF	National Science Foundation
OSHA	Occupational Safety and Health Administration
PAC	Powdered Activated Carbon
PDWB	Public Drinking Water Branch
PPE	Personal Protective Equipment
PTA	Packed Tower Aeration
PVC	Polyvinylchloride
RSMo	Revised Statutes of Missouri
SCADA	Supervisory Control and Data Acquisition
TOC	Total Organic Carbon
USC	United States Code
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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PREAMBLE

What is the Purpose of This Document?

This publication reflects the minimum standards and guidelines of the Missouri Department of Natural Resources in regard to the preparation, submission, review, and approval of engineering reports, plans, and facilities for the construction or alteration of community water systems. These standards are necessary for facilities to comply with the Missouri safe drinking water statutes and regulations.

These standards, consisting of proven technology, engineering principles, and sound water works practices, are intended to accomplish the following objectives: to serve as a guide for professional engineers in the design and preparation of engineering reports, plans, and specifications for community public water systems; to suggest limiting values for items upon which evaluation of such engineering reports, plans, and specifications are evaluated by the department; and to ensure that a new or altered community public water system facility will be capable of supplying adequate water in compliance with applicable regulations.

These standards draw heavily on the Recommended Standards for Water Works, commonly known as the “Ten State Standards.” The Great Lakes-Upper Mississippi Board of Public Health and Environmental Managers created a Water Supply Committee in 1950 consisting of one associate from each state represented on the Board (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin). In 1978, a representative of the Canadian province of Ontario was added. This committee was assigned the responsibility for reviewing existing water works practices, policies, and procedures, and reporting its findings to the Board. The report of the Water Supply Committee was first published in 1953, and has been updated and revised several times since then. The “Ten State Standards” are widely accepted throughout the water works industry as minimum standards for construction of safe water supplies. The 2007 edition of these standards were reviewed for the current revision of the Design Guide for Community Water Systems.

What Authority Is This Design Guide Based On?

The primary authority for oversight of public water system design and construction is the Missouri Safe Drinking Water Law 640.115(2) which states “Construction, extension or alteration of a public water system shall be in accordance with the rules and regulations of the safe drinking water commission”. The Missouri Safe Drinking Water Regulation 10 CSR 603.010(1) & (2) establishes the procedures for obtaining construction authorization, final construction approval and approval of a supervised construction program. The Missouri Safe Drinking Water Regulation 10 CSR 6010.010 sets the requirements for submission, review and approval of engineering reports, plans and specifications for community water supply planning and construction. The Missouri Safe Drinking Water Regulation 10 CSR 60-10.020 establishes requirements for siting of new or expanded water systems.

To Whom Do These Standards Apply?

These standards apply to new community water systems. These standards also apply to alterations made at existing community water systems. Only the portion of the existing community water system being modified is subject to these standards. These standards are not an inspection tool for assessing deficiencies in facilities constructed under approvals issued under previous Design Guides. However, where water quality, safety, or performance is an issue, appropriate portions of these minimum standards may be applied.

What Does This Document Require?

Where the terms "shall" and "must" are used, mandatory requirements are indicated. These terms are used where practice is sufficiently standardized to permit specific delineation of requirements or where safeguarding public health justifies such definite action. Other terms, such as "should," "recommended," and "preferred," indicate desirable procedures or methods, and deviations are subject to individual consideration, but these terms in no way indicate a requirement.

Deviation from the mandatory "shall" or "must" requirements will be considered by the department on a case-by-case basis, based on the primary purpose of the proposed water works, the local conditions governing their functions, and operation.

In many instances in this document, choices and alternatives are provided for meeting a requirement. For example, the engineering report shall include information on usage rates, water loss rates, unusual conditions, and population per service connection. That is the requirement. However, this information can be based on any one of four alternatives: (1) historical data from the water system if available; OR (2) data from a comparable system; OR (3) calculations of usage criteria using data specified in the document; OR (4) some other usage criteria if adequate justification is provided.

This approach provides flexibility in meeting basic requirements that ensure the proposed new or modified water system provides safe quality and adequate quantities of drinking water. This flexibility is provided where appropriate throughout the document.

Approval of the use of "other criteria," where that option is offered, must, of necessity, be somewhat subjective and situation-specific. However, the department feels it is important to allow this extra degree of flexibility to the water system and its engineers.

What Process Will the Department Use to Evaluate and Accept Alternative Designs?

See section 1.1.7

What Process is Available for Appealing the Department's Decision to Reject an Alternative Design?

See section 1.1.7

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Chapter 1 -- Submission of Plans

1.0 General

A minimum of two copies of all engineering reports, final plans, and specifications should be submitted at least 30 working days prior to the date on which action by the department is desired. A completed and signed department form MO 780-0701 "Application for a Construction Permit" shall be submitted with all detailed plans and specifications to the Public Drinking Water Branch at the following address:

> Missouri Department of Natural Resources
> Public Drinking Water Branch
> 1101 Riverside Drive
> P.O. Box 176
> Jefferson City, Missouri 65102-0176
> Attn: Permits and Engineering

Other federal, state, or local agencies may require permits for construction, waste discharges, stream crossings, etc. Preliminary plans and the engineer's report should be submitted for review prior to the preparation of final plans. No approval for construction shall be issued until final, complete, detailed plans and specifications have been submitted to the department and found to be satisfactory. Documents submitted for formal approval shall include but may not be limited to:

a. A summary of the basis of design, including hydraulic calculations sufficient to demonstrate the system will operate satisfactorily;
b. Identification of responsible party doing construction inspections along with their qualifications;
c. Applications for a construction permit;
d. Readily available cost estimates;
e. Specifications;
f. Detailed plans; and
g. General layout.

1.1 Engineering Report

An engineering report is required for the development of a new water supply system, new water sources, and expansions or alterations to existing water systems that will result in changes to the treatment process and/or overall production capacity. The engineering report shall, where pertinent, present the information listed in this chapter.

1.1.1. General information

General information, including:

a. The name and mailing address of the water system's continuing operating authority as defined in 10 CSR 60-3.020;
b. A description of the existing and proposed water system(s);
c. A description of the existing and proposed sewerage system and sewage treatment works as it affects the existing or proposed water system;

d. An identification of the water system, municipality (-ies) or area served with sufficient legible mapping so that the geographical area under concern is clearly understood and locatable; and

e. An imprint of professional engineer's seal or conformance with State of Missouri's engineering registration requirements.

1.1.2. Extent of the water system(s)

Extent of the water system(s), including the information in items a. through g. below:

a. A description of the nature and extent of the area to be served, including layout maps or drawings showing the legal boundaries of the water system(s).

b. Provisions for extending the water system to include additional areas.

c. Appraisal of the future requirements for service, including existing and potential residential, industrial, commercial, institutional, and other water supply needs.

d. Usage rates, water loss rates, unusual conditions, and population per service connection. This information shall be based on one or more of the alternatives listed in items 1. through 4.

1. Historical data from the public water system, if available. This data shall be representative of climatic conditions that affect demand and source.

2. When such historical data from the public water system are not available, data from a comparable water system may be used if a rational basis for the choice of the comparison is provided and is sufficiently detailed to clearly demonstrate the applicability.

3. If neither historical nor comparable water system data are available, the following information shall, as a minimum, be used for design purposes:

i. Population per service connection. Unless satisfactory justification can be given for using lower per-unit occupancies, the following numbers shall be used in determining the population for which to design the water works

Deleted: for permanent residential dwelling units including houses, mobile homes, condominiums, apartments, and multiplexes shall be approximately three (3.0) persons/dwelling unit

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Table 1 – Per Unit Occupancies

Service connection type	Persons/Unit
Residences	3.7
Apartments or Condominiums	
1 bedroom	2.0
2 bedroom	3.0
3 bedroom	3.7
Mobile homes	3.0-3.7
Camper trailers without sewer hookup	2.5
Camper trailers with sewer hookup	3.0
Motels	3.0

ii. Domestic water usage for residential dwelling units excluding lawn/garden irrigation usage shall be an average of 100 gallons per person per calendar day, except that for rural water districts this may be an average of 80 gallons per person per day.

4. Other usage criteria may be used in lieu of the criteria listed in the preceding item (1.1.2.d.3.) if the engineer provides adequate justification.

e. Lawn watering estimation may vary depending on the irrigation type, available flow, flow pressure, and area of coverage. Flow can be estimated from 0.75 – 3.0 GPM per sprinkler within a discharge pressure range of 35-100 PSI. In lieu of the above estimation, total flow can be estimated at 12 GPM per household.

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Housing Size Sprinkler Type Flow per House¶
Moderate/Middle Class End of Hose 1.25 ¶
Estate Automatic 2

f. Peak flow (instantaneous, one hour, two hour, three hour, or four hour) shall be based on:

1. Historical data on the public water system, if available from the water system. These data shall be representative of climatic conditions that affect demand and source. If historical data is used, the entire distribution system hydraulics shall be calculated;
2. If such historical data from the public water system are not available, data from a comparable water system may be used; or
3. If neither historical nor comparable water system data are available, the following information shall be used for design purposes:

Instantaneous Peak Flow = Domestic Peak Flow* + Lawn/Garden Irrigation Peak Flow + Commercial, Larger Users, Confined Feeding Operations

*Domestic peak flow should be calculated as the greater of:

1. One gallon per minute per connection, or
2. Peak = $12(N)^{0.515}$
   Where 'N' stands for number of connections

4. Other peak flow criteria may be used in lieu of the criteria listed in the preceding item (1.1.2.f.3.) if the engineer provides adequate justification; for example, rural water districts may calculate domestic peak flow as the greater of 0.75 gallons per minute per connection or Peak = $9(\text{number of connections})^{0.515}$.

g. Maximum day flow shall be based on:

1. Historical data if these data are available from the public water system. This data shall be representative of climatic conditions that affect demand and source);
2. If historical data are not available, data from a comparable system may be used; or
3. If neither historical nor comparable data are available, the following information may be used for design purposes:

Maximum Day Flow = 150% of Average Day Flow

4. Other maximum day flow criteria may be used in lieu of the criteria in the preceding item (1.1.2.g.3.) if the engineer gives adequate justification.

1.1.3. Soil, ground water conditions, and foundation problems

The engineering report shall specifically address whether the native soils are suitable for main bedding and backfill and note the extent that crushed stone, gravel or other purchased bedding/backfill will be needed, along with estimated costs. The report shall also address the potential for rock excavation in the various soils encountered, along with estimated costs.

1.1.4. Flow requirements

Flow requirements, including:

a. Hydraulic analyses based on flow demands and pressure requirements (see Chapter 8 of this document); and
b. Fire flows, when fire protection is provided, design shall be based on the Insurance Services Office (ISO) Fire Flow Criteria.

1.1.5. Sources of water supply

Describe the proposed source or sources of water supply to be developed, the reasons for their selection, and provide information as follows:

1.1.5.1. Surface water sources

Including where pertinent:

a. Hydrological data, stream flow, and weather records;
b. Safe yield design as described in section 3.1. of this document;
c. The maximum flood flow and the safety features of the spillway and dam, shall be based on the design criteria of the Missouri Dam and Reservoir Safety Council, regardless of the height of the dam;
d. A description of the watershed, noting any existing or potential sources of contamination (such as highways, railroads, chemical facilities, farming operations, etc.) which may affect water quality, a discussion of land use practices, and provisions for erosion and siltation control structures;
e. Summarized quality of the raw water, with special reference to fluctuations in quality, changing meteorological conditions, etc.; and
f. Source water protection issues or measures that need to be considered or implemented. (See 3.1.2)

1.1.5.2. Ground water sources

The department shall be consulted prior to design and construction regarding a proposed well location as it relates to required separation between existing and potential sources of contamination and groundwater development. The engineering report shall include-

1. A legal description of sites under consideration;
2. Advantages of the selected site;

3. Elevations with respect to surroundings;
4. Probable character of formations through which the source is to be developed;
5. Geologic conditions affecting the site; for example, any existing sinkholes, caves, test holes, abandoned wells, or anticipated interference between proposed and existing wells.
6. A summary of source exploration, test well depth, and method of construction, placement of liners or screen, test pumping rates and their duration, location, sieve analysis, water levels and specific yield, and water quality;
7. Existing wells within 300 feet radius of the proposed well site, giving their depths, protective casing depths, capacities, and location;
8. Sources of possible contamination within 300 feet; such as sewers and sewerage facilities, highways, railroads, landfills, outcroppings of consolidated water-bearing formations, chemical facilities, waste disposal wells, etc; and
9. Wellhead protection measures being considered.

1.1.6. Alternate plans

Where two or more solutions exist for providing public water supply facilities, each of which is feasible and practicable, discuss the alternate plans. Give reasons for selecting the solution recommended, including financial considerations, and a comparison of the certification level of water system operator required.

1.1.6.1 Evaluation

It is not possible to cover recently developed processes and equipment in a publication of this type. However, it is the policy of the department to encourage rather than obstruct the development of new processes and equipment. Recent developments may be acceptable if they meet at least one of the following conditions:

1. They have been thoroughly tested in full scale comparable installations under competent supervision;
2. They have been thoroughly tested as a pilot plant operated for a sufficient time to indicate satisfactory performance; or
3. A performance bond or other acceptable arrangements have been made so the owners or official custodians are adequately protected financially or in case of failure of the process or equipment.

Regardless of the alternative data presented, the basic criteria for evaluating its merit remains the same: Does the alternative criteria offer a comparable level, quantity, and quality of information as the other options offered in the document (usually historical or comparable data or specific calculations), and does the data demonstrate that the alternative design provides equivalent or superior performance under the anticipated extreme operating conditions?

1.1.6.2 Appeals Process

While the review of most project and construction documents proceeds in a relatively innocuous manner, culminating in an approval being issued, there are times when the PDWB staff engineer and the water system or its consultant may be unable to reconcile a difference. The water system owner/operator may pursue a formal appeal of the department's decision to the Safe Drinking Water Commission, through the authority provided affected parties in section 640.010.1, RSMo; however, the PDWB recommends that the following dispute resolution process be followed prior to resorting to formal procedures:

1. If the PDWB staff engineer determines that the proposed design does not meet regulatory criteria or acceptable engineering practices as established in this document, the PDWB engineer will explain, in writing, the basis for the decision.
2. If the system or its design engineer or consulting engineer disagrees with the PDWB staff engineer's written conclusion, the design or project engineer must submit the basis of their disagreement, in writing, to the PDWB staff engineer.
3. The PDWB staff engineer will share the information submitted by the design or project engineer with management and other professional engineers in the PDWB and solicit their opinions regarding the design or project engineer's response.
4. The PDWB's position on the specific issue will be established by the program director. The PDWB program director's response will be provided to the water system and its engineer(s) within 30 calendar days of the receipt of the system's response identified in item 2, above.
5. If the water system's owner/operator or consulting engineer remains in disagreement with the department's position, a formal appeal process could be initiated, as applicable, under the authority provided in section 640.010.1, RSMo.

1.1.7. New technology

The technologies provided in these design standards are generally based on standards of the American Water Works Association, Recommended Standards for Water Works (commonly called "Ten States Standards"), and other nationally recognized standards. These technologies have a long history of use and can be reasonably expected to perform satisfactorily. However, it is the policy of the department to encourage new technologies for the production, treatment, and distribution of drinking water while continuing to protect the public health.

The criteria for evaluating the merits of new technologies are as follows:

a. That the new technology provides equivalent or superior performance under extreme operating conditions to existing proven technologies;

b. It provides equivalent or superior reliability of service consistent with the operation and maintenance capabilities of the system for which the design is proposed; and

c. It provides equivalent or superior costs of operation and maintenance to existing proven technologies.

Any public water system proposing a new technology not addressed in these design standards shall provide and meet the following additional requirements.

1.1.7.1. Engineering Report--Additional requirements for new technology

a. Complete description of the new technology including the scientific principles upon which the technology is based;

b. A statement indicating if the technology is currently protected by U.S. patents or is otherwise proprietary;

c. Results of full scale operations at other public water systems, with water similar to that of the public water system proposing the installation or pilot studies.

d. Pilot studies shall:

   1. Have protocols including proposed testing parameters approved by the department prior to initiating the pilot study;
   2. Be done in a manner that will assure an acceptable quality of finished water will be produced through all seasonal water quality variations of the source water;
   3. Include a research of historic data to determine the extremes of water quality that may be encountered and the research results submitted in the results of the pilot study submitted with the engineering report;
   4. Be conducted under the same operating parameters as the proposed full scale system;
   5. Include an assessment of the costs of operation, replacement, and maintenance to be included in the results of the pilot study submitted with the engineering report; and
   6. Be done in a manner to show repeatability of performance under the same operating conditions and the effects of long term operation.

e. The expected design life of each equipment component used in the new technology and the present day replacement cost of each component including both material cost and labor cost;

f. A complete description of the training needed for public water system personnel to operate and maintain the new technology including the number of days of training and the cost of training. If initial training is provided with the purchase price, the cost of training additional operators or maintenance personnel must be identified to cover personnel turnover;

g. The estimated number of minutes or hours needed per day, week, month, quarter, or year (as appropriate) including any down time expected to operate and maintain the components of the new technology. Any expected maintenance or repairs that must be done by vendor or factory personnel must also be identified along with costs, frequency, and down time;

h. The estimated costs of operating and maintaining the new technology;

i. A complete description of standard technology including detailed cost estimates of material, labor, engineering, and contingency that would be needed to replace the new technology in the event the new technology is found to be ineffective; and

j. A complete list of operating records, maintenance records, cost records, and testing protocol needed to evaluate the performance of the new technology.

1.1.7.2. Financial certification.

The public water system chief financial officer (or equivalent official if appropriate) shall provide written certification to the department that the system has financial resources that are adequate to operate and maintain the new technology and to replace the new technology with standard technology should the new technology be found to be ineffective. This certification shall include the nature of the financial resources, which may include but is not limited to:

a. Cash reserves in bank accounts
b. U.S. Government securities
c. Other investments (stocks, bonds, mutual funds, precious metals, etc.)
d. Local bonds passed for this project but left in reserve to cover this contingency
e. Binding agreement with a government funding agency to provide the funding needed to replace the new technology if it proves ineffective
f. A performance bond meeting the conditions noted in the Performance Contract
g. Projected annual operating fund surpluses.

1.1.7.3. Performance contract

The public water system shall enter into a contract with the department that includes the following elements: (A less stringent method would be a written certification instead of a contract)

a. The new technology shall be deemed ineffective if use of the technology results in a maximum contaminant level violation, action level violation, or treatment technique violation listed in 10 CSR 60 during any three months during a running 12-month period over the life of the performance period;

b. The new technology shall be deemed ineffective if use of the technology results in water outages or pressure reduction below 20 pounds per square inch gage (20 psig) during any three months during a running 12-month period over the life of the performance period;

c. The public water system shall maintain financial resources to replace the new technology with standard technology during the life of the contract. The reserve funds needed shall be initially based on the standard technology cost estimate from the engineering report and shall be increased annually for inflation using the federal consumer price index (or other suitable index);
d. The public water system will provide the operation and maintenance, including operator and maintenance personnel training, as outlined in the engineering report;
e. The public water system will collect and record all operation, maintenance, and cost records and perform all analysis outlined in the engineering report;
f. The public water system shall obtain the services of a professional engineer registered in Missouri to oversee data collection, record keeping, and provide a complete engineering analysis of the new technology after one year of operation, after the performance period is completed, and (if needed) following the department issuing a preliminary intent to declare the technology ineffective for this public water system. The professional engineer shall submit two copies of the engineering analysis to the department within six months of the end of the first year, within six months of the end of the performance period, and within six months of the department issuing a preliminary intent to declare the technology ineffective for this public water system. This engineering analysis shall evaluate the effectiveness of the new technology for its intended purpose and list all data and calculations supporting this evaluation, note any problems with operation or maintenance and including how, when, or if these problems were solved, note actual times spent operating and maintaining the new technology and compare these with those estimated in the engineering report, calculate costs of operating and maintaining the new technology and compare these with those estimated in the engineering report, complete a reassessment of the expected life of major components of the new technology, include the engineer's conclusion as to whether or not this technology was effective for this public water system and include the engineer's recommendation (with any reservations) as to whether or not this technology should be widely approved for similar application;
g. If the public water system has maximum contaminant level violations, action level violations, treatment technique violations, or low pressure violations at the frequency noted above in items a. and b., that, in the department's opinion, could be the result of use of the new technology, the department shall issue a preliminary intent to declare the new technology ineffective for this public water system. The public water system shall then submit the engineering evaluation within the time frame noted above in item f.;
h. The department shall review the engineering evaluation and conduct other investigations as it deems necessary including, but not limited to,

investigations by department employees or contractors, invitations to submit analysis from the vendor, manufacturer, and original project engineer (if different from the evaluation engineer). Within six months of submittal of the engineering evaluation by the public water system, the department shall make a formal determination of whether or not the new technology is ineffective for this public water system; and

i. If the department formally determines the new technology is ineffective for this public water system, the public water system shall:
    1. Within 180 calendar days, submit engineering plans and specifications prepared by a professional engineer registered in Missouri and a completed construction permit application to the department for replacing the new technology with the standard technology identified in the original engineering report;
    2. Within 30 calendar days of receipt of any request from the department for additional information or changes in the engineering plans and specifications, the public water system shall submit these alterations to the department;
    3. Within 180 calendar days of the department's approval to construct, the public water system shall construct the new facilities; and
    4. Within 21 calendar days of completion of construction, the public water system shall submit certification by the professional engineer stating that the project has been substantially completed in accordance with the approved plans and specifications to the department.

1.1.7.4. Performance period.

The length of the performance period shall be the lesser of 60 months or the expected life of the major components of the new technology. The life of the contract shall be the performance period plus 12 months, which includes six months for the engineering analysis and six months for the department's final determination of effectiveness.

1.1.7.5. Performance follow-up

Initially, the department will approve only one project for a particular new technology statewide. After the department completes review of the one year engineering evaluation of this first project, the department may approve an additional nine projects for a particular new technology statewide. If any project is formally declared to be ineffective, all approvals shall cease until the department reassesses the new technology and determines if the failure was site specific or more general.

After the completion of ten successful projects for a particular new technology and department review of all engineering evaluations, the department may promulgate design regulations allowing the new technology to become standard technology or may allow additional projects to gather more information if needed. Ultimately, the department will either promulgate regulations making the new technology standard technology or will declare the new technology inappropriate for use in Missouri.

1.1.8. Project Sites.

The area and approximate geometry of the proposed site shall be identified and the adequacy for adding additional facilities on the site, and for providing adequate security. The proximity of residence, industries and other establishments shall be identified and their affect on the safety, security, operation and maintenance of facilities. Systems shall not be located on sites:

a. That are subject to a significant risk from earthquakes, floods, fires, pollution or other disasters which could cause a breakdown of the public water system or a portion of the system, and, except for intake structures, are within the floodplain of a 100-year flood where appropriate records exist; and
b. With any potential sources of pollution or other factors that may influence the quality of the supply or interfere with effective operation of the water works system, such as sewage absorption systems, septic tanks, privies, cess-pools, sinkholes, sanitary landfills, refuse and garbage dumps.

1.2. Plans.

Plans for water systems shall be legible and no larger than standard size 24 inches by 36 inches.

1.2.1. Plans shall include the following:

a. Suitable title identifying the project, and index;
b. The name of the Continuing Operating Authority responsible for the water supply;
c. The name of the public water supply system, or proposed public water supply system;
d. The public water supply system's ID number
e. Scale, in feet;
f. North point;
g. Latest U.S.G.S. datum and topographical elevations for new and existing tanks determined from surveys beginning at USGS or department elevation monuments;
h. Legible prints suitable for reproduction;
i. Date, name, and address of the designing engineer;
j. Imprint of professional engineer's seal in conformance with State of Missouri's engineering registration requirements;
k. Boundaries of municipality, water district, or area to be served;
l. Location and size of existing water mains;
m. Location and nature of existing water system structures and appurtenances affecting the proposed improvements, noted on one sheet;
n. Location and description of existing and/or proposed sewerage system;
o. Location of proposed water mains and water system structures, with size, length and identity;
p. Contour lines at suitable intervals; and

q. Names of streets and roads.

1.2.2. Detailed plans, including:

a. Stream crossings, providing profiles with elevations of the streambed, geology under the stream bed and the normal and extreme high and low water levels;
b. Profiles, where necessary, having a horizontal scale of not more than 100 feet to the inch and a vertical scale of not more than ten feet to the inch, with both scales clearly indicated. (Note: This does not apply to entire distribution systems.);
c. Location and size of the property to be used for the water works development with respect to known references such as roads, streams, section lines, or streets;
d. Topography and arrangement of present or planned wells or structures, with contour intervals not greater than two feet;
e. One hundred-year flood plain or elevations of the highest known flood level, floor of the structure, upper terminal of protective casings and outside surrounding grade, using United States Coast and Geodetic Survey, United States Geological Survey or equivalent elevations where applicable as reference;
f. Plat and profile drawings of well construction, showing the diameter and depth of drill holes and casings; liner diameters; grouting depths; elevations and designation of geological formations; water levels and other details to describe the proposed well completely;
g. Location of all existing and potential sources of pollution within 1,000 feet of the source, and within 300 feet of underground treated water storage facilities;
h. Size, length, and identity of sewers, drains, and water mains, and their locations relative to plant structures;
i. Schematic flow diagrams and hydraulic profiles showing the flow through various plant units;
j. All piping in sufficient detail to show dimensions, elevations, sectional views, and flow through the plant, including waste and chemical feed lines;
k. Locations of all chemical storage areas, feeding equipment, and points of chemical application;
l. All appurtenances, specific structures, equipment, water treatment plant waste disposal units, and points of discharge having any relationship to the plans for water mains and/or water system structures;
m. Locations of sanitary or other facilities, such as lavatories, showers, toilets, floor drains, etc;
n. Locations, dimensions, and elevations of all proposed plant facilities;
o. Locations of all sampling taps;
p. Dimensional plans of elevation, sectional and detailed views of all reinforced concrete metallic tankage; and
q. Adequate description of any features not otherwise covered by the specifications.

1.3. Specifications.

Complete, detailed technical specifications shall be supplied for the proposed project, including:

a. A description of how existing water system facilities will continue in operation during renovation or construction of additional facilities to minimize interruption of service;
b. The specification of laboratory facilities and equipment;
c. The number and design of chemical feeding equipment;
d. A description of materials or proprietary equipment for sanitary or other facilities including necessary cross-connection protection;
e. The specification of manufactured products such as pipe, valves, fittings, hydrants, steel, Portland cement, etc. by the appropriate national standard, sufficient to differentiate the exact product. Any stamp or marking required to identify the product as meeting the national standard and an affidavit from the manufacturer stating that the product meets the national standard. The standard names, number, effective date, publication date, name and address of the organization issuing the standard shall identify the national standard. Specifications for manufactured products may also include the complete detailed national standard at the discretion of the engineer;
f. All procedures, methods, testing requirements, and products except manufactured products noted in paragraph 1.3.e. above, specified by the appropriate national standard and all details of the national standard needed to properly construct the water system component shall be included in the specifications. The standard name, number, effective date, publication, name and address of the organization issuing the standard shall identify the national standard;
g. Where performance specifications are used, shop drawings must be provided;
h. Provisions for training of system operators to be provided by equipment manufacturers or suppliers concerning the operation and maintenance of the new facilities. The fulfillment of the training requirements will not be complete until system officials certify that adequate training has been provided;
i. Requirement for operation and maintenance manuals to be provided to the system by equipment manufacturers or suppliers on equipment and systems installed;
j. Requirements that coatings, sealants, piping, fittings, appurtenances and materials in direct contact with the water shall meet National Science Foundation (NSF) Standard 61 to prevent imparting of harmful substances into the water; and
k. An executive summary describing the way a SCADA or other process instrument control system is intended to function.

1.4. Summary of Design Criteria.

A summary of complete design criteria shall be submitted for the proposed project, containing but not limited to the following:

a. Long-term dependable yield of the source of supply;
b. Reservoir surface area, volume, and a volume-versus-depth curve;
c. Area of watershed;
d. Estimated average and maximum day water demands for the design period. Number of proposed services;

f. Fire fighting requirements;
g. Flash mix, flocculation and settling basin capacities;
h. Retention times;
i. Unit loadings;
j. Filter area and the proposed filtration rate;
k. Backwash rate; and
l. Chemical feeder capacities and ranges.

1.5. Additional Information Required.

The department may require additional information, which is not part of the construction drawings, such as head loss calculations, proprietary technical data, copies of deeds, copies of contracts, shop drawings, etc.

1.6. Revisions to Approved Plans.

a. Any deviation from approved plans or specifications affecting capacity, hydraulic conditions, operating units, the functioning of water treatment processes, or the quality of water to be delivered must be approved in writing before such changes are made.
b. Revised plans or specifications shall be submitted to the department for review and approval before any construction work affected by such changes is started.

1.7. Final Approval of Construction.

a. Final construction approval or a written interim approval to operate must be obtained from the department for all projects for which approval is required before that project is placed into service.
b. Upon completion of the construction, the engineer must:
   1. Notify the department and establish a mutually satisfactory time for making a final inspection, certify in writing that the construction is substantially completed in accordance with approved plans and specifications and change orders;
   2. Submit two copies of as-built plans to the department;
   3. Show that water quality is acceptable to the department;
   4. Submit the final cost of the project with all components of cost identified.
   5. Provide O&M manuals to system operators on systems and equipment installed; and
   6. Submit a statement of work completed.
c. In larger projects, an interim (partial) approval may be secured for the completed parts of the water system before they are placed in service.

1.8. Supervised Program.

a. A supplier of water may apply for an owner supervised program in lieu of submitting plans and specifications for expansion and/or alteration of an existing water distribution system.
b. A written request to the Department of Natural Resources for approval of a supervised program must include the following information:

1. An engineer prepared report or a master plan showing the proposed waterlines over at least the next five years, along with engineering rationale, including hydraulic analyses, for sizing and locating the lines. The engineering report must discuss adequacy of present water system with regard to the source, storage and existing distribution piping, discuss problems that need to be resolved (leaks, low pressures, etc.), discuss fire protection needs (if applicable). A priority listing of proposed improvements along with cost estimates should also be included in the engineering report;
2. A current layout map, or maps, of the distribution system (standard size 24" x 36"). The map(s) must show waterline sizes (existing and proposed), location of valves, fire hydrants and flushing devices, along with street names;
3. Adoption of a minimum pipe size for waterline replacements not otherwise shown on the master plan which will maintain a minimum pressure in accordance with Chapter 8 of this document;
4. Examples of permanent records and drawings of the distribution system including lines, valves, hydrants and cleanouts. Record plans must be large enough scale and provide sufficient detail to locate lines, valves and other appurtenances for excavation using only the plans;
5. Technical specifications prepared by an engineer covering construction materials, installation, and disinfection procedures in accordance with American Water Works Association standards;
6. Typical detail drawings by an engineer of special crossings, meter settings, valve settings, hydrant settings, cleanouts, thrust blockings, etc;
7. A brief statement about qualifications of the person responsible for construction inspection;
8. A description as to how permanent records and drawings will be provided. If permanent records and drawings are to be prepared by a consulting engineer, a copy of the agreement with the firm must be provided; and
9. Examples of inspection forms to be used to inspect water mains and appurtenances.

Chapter 2 - General Design Considerations

2.0. General.

The design of a water supply system or treatment process encompasses a broad area. Application of this chapter depends on the type of system or process involved.

2.1. Design Basis.

The system shall be designed for maximum day demand at the design year.

2.2. Plant Layout.

Design of new treatment plants, well houses and pump stations shall consider:

a. Functional aspects of the plant layout;
b. Provisions for future plant expansion;
c. Provisions for expansion of the plant waste treatment and disposal facilities;
d. Access roads, driveways, walks, and fencing;
e. Site grading and drainage;
f. Chemical delivery;
g. Security of facilities; and
h. Provisions for safety

2.3. Building Layout.

Design shall provide for:

a. Adequate ventilation, lighting, emergency lighting, heating, and floor drainage;
b. Dehumidification equipment, if necessary;
c. Accessibility of equipment for operation, servicing, and removal;
d. Flexibility of operation, convenience of operation, and operator safety;
e. Chemical storage and feed equipment in separate rooms to reduce hazards and dust problems;
f. Adequate facilities should be included for shop space and storage, consistent with the designed facilities; and
g. Adequate number of emergency exits.

2.4. Site Selection Requirements.

a. Site must not be subject to a significant risk from floods, fires, pollution, or other disasters, which could cause a breakdown of the public water supply system or portion thereof.
b. Non-submersible intake pumping equipment and accessories must be located or protected to at least four feet above the 100-year flood elevation or the highest flood elevation on record.
c. The department must be consulted regarding any structure that may impede normal or flood stream flows.
d. In earthquake prone areas, structures should be designed to withstand earthquake effects.
e. The site will provide all-weather access road to all significant facilities.

2.5 Security Measures

a. All water system facilities shall be designed to include measures to provide protection against vandalism, sabotage, terrorist acts, or access by unauthorized personnel. These protection measures shall include:

1. Lockable doors and access ways;
2. Secured outdoor electrical and control systems
3. Windows designed to deter human entrance;
4. Exterior lighting around the perimeter of treatment facilities, pumping stations, well houses, finished water storage facilities and other important facilities to deter vandalism and sabotage; and
5. Security fencing around vulnerable areas of drinking water facilities such as treatment and storage facilities, pumping stations and wells with signs prohibiting unauthorized access.

2.6. Electrical Controls.

Main switch gear electrical controls shall be located above grade, and in areas not subject to flooding.

2.7. Standby Power.

For the system's own protection, standby power or an alternate power source should be provided so that water may be treated and/or pumped to the distribution system during power outages to meet average day demand. Systems serving a population of 3,300 or greater shall have arrangements in place for standby or backup power and shall include these arrangements in their emergency operating plan.

2.8. Laboratory Equipment.

Each public water supply shall have its own equipment and facilities for routine laboratory testing necessary to ensure proper operation. Laboratory equipment selection shall be based on the characteristics of the raw water source and the complexity of the treatment process involved. Laboratory test kits that simplify procedures for making one or more tests may be acceptable. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately certified laboratory in accordance with "Standard Methods for the Examination of Water and Wastewater", methods recommended by the USEPA in their list of approved methods or by methods approved by the department. Persons designing and equipping facilities for which laboratory certification by the department is desired shall confer with the department before beginning the preparation of plans or the purchase of equipment. Methods for verifying adequate quality assurance and for routine calibration of equipment shall be provided.

2.8.1. Testing equipment.

a. Surface water supplies:

1. Shall have a bench model Nephelometric turbidimeter to monitor entry point to the distribution system;
2. Shall have continuous Nephelometric turbidity monitoring and recording

equipment on each filter located to monitor effluent and filter to waste;
2. Shall have electrode pH meter;
3. Shall have equipment necessary to perform jar test;
4. Shall have titration equipment for both hardness and alkalinity; and
5. Should provide the necessary facilities for microbiological testing of water from both the treatment plant and the distribution system.

b. Groundwater supplies, where pertinent:
1. Shall have test equipment capable of accurately measuring iron and manganese to a minimum of 0.05 milligram per liter;
2. Shall have electrode pH meter;
3. Shall have titration equipment for both hardness and alkalinity; and
4. With lime softening facilities, should have a Nephelometric turbidimeter.

c. Public water supplies that**:**
1. Chlorinate shall have test equipment for determining both free and total chlorine residual by methods in "Standard Methods for the Examination of Water and Wastewater";
2. Fluoridate shall have test equipment for determining fluoride by methods in "Standard Methods for the Examination of Water and Wastewater"; and
3. Feed polyphosphates and/or orthophosphates shall have test equipment capable of accurately measuring phosphates from 0.1 to 20 milligrams per liter.

2.8.2. Physical facilities.

Sufficient bench space, adequate ventilation, adequate lighting, electrical receptacles, storage room, laboratory sink, and auxiliary facilities shall be provided. Air conditioning may be necessary.

2.9. Monitoring and Recording Equipment.

Water treatment plants with a capacity of 0.5 MGD or more should be provided with continuous monitoring and recording equipment to monitor water being discharged to the distribution system as follows:

a. Plants treating surface water and plants using lime for softening should have the capability to monitor and record free chlorine residual and pH. In addition, continuous monitoring of entry point disinfection residuals shall be provided for systems with a service population greater than 3,300 people. Monitoring of the parameters to evaluate adequate CT disinfection, such as residuals, pH and water temperature, should be provided; and
b. Plants treating ground water using iron removal and/or ion exchange softening should have the capability to monitor and record free chlorine residual.

2.10. Plant Sample Taps.

a. Sample taps shall be provided so that water samples can be obtained from each water source and from appropriate locations in each unit operation of treatment.
b. Taps shall be consistent with sampling needs and shall not be of the petcock type.
c. Taps used for obtaining samples for bacteriological analysis shall be of material that resist flaming, smooth-nosed type without interior or exterior threads, shall not be of

the mixing type, and shall not have a screen, aerator, or other such appurtenances.

2.11. Facility Water Supply.

a. The facility water supply service line and the plant finished water sample tap shall be supplied from a source of finished water at a point where all chemicals have been thoroughly mixed, and the required disinfectant contact time has been achieved.
b. There shall be no cross-connections between the facility water supply service line and any piping, troughs, tanks, or other treatment units containing wastewater, treatment chemicals, raw or partially treated water.

2.12. Wall Castings.

Consideration shall be given to providing extra wall castings built into the structure to facilitate future uses whenever pipes pass through walls of concrete structures.

2.13. Meters.

All water supplies shall have an acceptable means of metering the raw water flow, finished water flow, flow through the treatment plant, and treatment plant service flow.

2.14. Piping Color Code.

a. To facilitate identification of piping in plants and pumping stations the color scheme in Table 1 is recommended.

Table 2 – Piping Color Code

TYPE OF PIPE	PIPE COLOR
WATER LINES	
Raw	Olive
Settled or Clarified	Aqua
Finished or Potable	Dark Blue
CHEMICAL LINES	
Alum or Primary Coagulant	Orange
Ammonia	White
Carbon Slurry	Black
Caustic	Yellow with Green Band
Chlorine (Gas and Solution)	Yellow
Fluoride	Light Blue with Red Band
Lime Slurry	Light Green
Ozone	Yellow with Orange Band
Phosphate Compounds	Light Green with Red Band
Polymers or Coagulant Aids	Orange with Green Band
Potassium Permanganate	Violet
Soda Ash	Light Green with Orange Band
Sulfuric Acid	Yellow with Red Band
Sulfur Dioxide	Light Green with Yellow Band
WASTE LINES	

Backwash Waste	Light Brown
Residuals	Dark Brown
Sewer (Sanitary or Other)	Dark Gray
OTHER	
Compressed Air	Dark Green
Gas	Red
Other Lines	Light Gray

In situations where two colors do not have sufficient contrast to easily differentiate between them, a six - inch band of contrasting color should be on one of the pipes at approximately 30-inch intervals. The name of the liquid or gas should also be on the pipe. In some cases, it is also advantageous to provide arrows indicating the direction of flow.

2.15. Disinfection.

All wells, pipes, tanks, and equipment which can convey or store potable water shall be disinfected in accordance with the current AWWA procedures. Plans or specifications shall outline the procedure and include the disinfectant dosage, contact time, and method of testing the results of the procedure.

2.16. Manuals and Parts List.

An operation and maintenance manual including a parts list and parts order form shall be supplied to the water system as part of any proprietary unit installed in the facility. Written instruction for the start-up of the plant or pumping station shall be provided to the water system owner.

2.17. Other Considerations.

Consideration must be given to the design requirements of other federal, state, and local regulatory agencies for items such as safety requirements, special designs for the handicapped, plumbing and electrical codes, construction in a flood plain, etc.

2.18. Automation.

The department encourages measures, including automation, which assist operators in improving plant operations and surveillance functions. Automation is not a substitute for qualified manned operation and maintenance and all treatment plants must be manned by qualified operators for what the department determines to be an appropriate part of each working day. Off hours automated operation of groundwater treatment facilities will be considered on a case by case basis. Automated, unmanned, unsupervised operation of a surface water treatment facility does not adequately protect public health and is generally not acceptable. Automation of surface water treatment facilities to allow unattended operation with manned off-site control presents a number of management and technological challenges that must be overcome before an approval can be considered. Automation of any type of treatment facility requires that each facet of the plant facilities and operations must be fully evaluated to determine what on-line monitoring is appropriate, what alarm capabilities must be incorporated into the design and what staffing is necessary. Consideration must be given to the consequences and operational response to treatment challenges, equipment failure and loss of communications or power.

The engineering report to be submitted to the department for review must cover all aspects of the treatment plant and automation system including the following information/criteria:

1. Identification of all critical features in the pumping and treatment facilities that will be electronically monitored, have alarms that directly contact a qualified operator and can be operated automatically or off-site via the control system. Include a description of automatic plant shutdown controls with alarms and conditions that would trigger shutdowns. Dual or secondary alarms may be necessary for certain critical functions;
2. Provision for automated monitoring of all critical functions with major and minor alarm features. Automated plant shutdown is required on all major alarms. Automated remote startup of the plant is prohibited after shutdown due to a major alarm. The control system must have response and adjustment capability on all minor alarms. Built-in control system challenge test capability must be provided to verify operational status of major and minor alarms;
3. The plant control system that has the capability for manual operation of all treatment plant equipment and process functions;
4. A plant flow diagram that shows the location of all critical features, alarms and automated controls to be provided;
5. Description of off-site control station(s) that allow observation of plant operations, receiving alarms and having the ability to adjust and control operation of equipment and the treatment process;
6. Description of optimal staffing for the plant design, including meeting requirements in 10 CSR 60-14.010 for certified operators; an on-site check at least once per day by a certified operator to verify proper operation and plant security; and sufficient appropriate staffing to carry out daily on-site evaluations, operational functions, and maintenance and calibration of all critical treatment components and monitoring equipment and weekly checks of the communication and control system to ensure reliability of operations. Challenge testing of such equipment should be part of normal maintenance routines;
7. Description of operator training planned or completed in both process control and the automated system;
8. Operations manual, which gives operators step-by-step procedures for understanding and using the automated, control system under all water quality conditions. Emergency operations during power or communications failures or other emergencies must be included;
9. A plan for a 6-month or more demonstration period to prove the reliability of procedures, equipment and surveillance system. A certified operator must be on duty during the demonstration period. The final plan must identify and address any problems and alarms that occurred during the demonstration period. Challenge testing of each critical component of the overall system must be included as part of the demonstration project;
10. A schedule for maintenance of equipment and critical parts replacement;
11. Provision for sufficient finished water storage to meet system demands and CT requirements whenever normal treatment production is interrupted as the result

of automation system failure or plant shutdown; and

12. Provision for ensuring security of the treatment facilities at all times. Incorporation of appropriate intrusion alarms must be provided which are effectively communicated to the operator in charge. See section 2.5 Security Measures.

Chapter 3 - Source Development

3.0. General.

In selecting the source of water to be developed, the design engineer must prove that an adequate quantity of water will be available. The proposed groundwater or surface water supply must be adequate for future water demands during the design period. Water that is to be delivered to the consumers will meet the current requirements of the department with respect to microbiological, physical, chemical and radiological qualities. Each water supply should take its raw water from the highest quality and sustainable source that is economically reasonable and technologically possible.

3.1. Surface Water.

A surface water source includes all tributary streams and drainage basins, natural lakes, and artificial reservoirs above the point of water supply intake. A source water protection plan enacted for continued protection of the watershed from potential sources of contamination should be developed by the Continuing Operating Authority for all new surface water sources.

3.1.1. Quantity.

a. Reservoir storage volume shall provide a reasonable surplus for reserve storage and anticipated growth. A reasonable amount of surplus reserve storage should be considered in order to maintain public confidence in the reliability of supply at predicted depletion levels during a prolonged severe drought. A minimum of 120 days surplus reserve storage should be considered.

b. Reservoir storage volume shall be adequate to compensate for all losses such as silting, evaporation, seepage, stagnation, and required discharges to maintain downstream flows.

c. When multiple water sources are provided, the amount of water needed from the proposed reservoir shall be stated and that amount plus water losses due to sediment, evaporation, seepage, and stagnation shall be used to design the reservoir capacity.

d. The capacity of a water supply reservoir shall be determined by using a reservoir operations model such as the USDA Natural Resource Conservation Service's Procedures for Determining Runoff and Reservoir Operation Study. A reservoir study shall be conducted for the drought of record using future design period demand for the water system. The design draft shall include water losses due to sediment, evaporation, seepage, and stagnation as well as the predicted water system demand. Losses due to sediment shall be the accumulated loss predicted at the end of the design period of the reservoir. Climatic data such as precipitation and evaporation used shall be as specific to the proposed reservoir site as is possible. The usable quantity of water in a reservoir shall be sufficient to provide carryover storage at all design future demands and shall include a sufficient reserve to maintain public confidence in the reliability of supply at predicted depletion levels. Water supply availability and storage capacity must meet future water demands of all water users through the multiyear drought of record, presently from 1953 through 1958.

e. When a river or stream is to be used as the sole source of water, the flow in the river or stream shall exceed the current registered and future downstream uses, instream flow recommendations, usually the 7 day Q 10 flow rate, and the design year future water system demand. Historical data must be used to determine that stream flows are adequate. Where the nearest gauging station is downstream of the intake site, a drainage area ratio or other approved method to represent the intake location must adjust the flow data. Data from an upstream station may be used. For streams where data does not cover the drought of record, data from similar streams may be used to correlate or predict stream flows, with department approval.

The necessary permits and approvals to install an intake into a stream or river shall be obtained. The conditions on a permit may significantly affect the quantity and rate that may be pumped and the carryover storage required. The usable capacity of the raw water storage reservoirs shall provide carryover storage for the worst case conditions of record. Design demand analysis from the stream or river shall meet all predicted system demands, shall meet permit conditions, shall include the ability to refill the off-stream reservoirs and shall account for evaporation and seepage from all the reservoir storage structures.

f. Where pumping is used to supplement runoff to a water supply reservoir, a reservoir operation study shall be developed to determine if stream flows, runoff and carryover storage are adequate. The design demand shall include water losses due to evaporation and seepage, all reservoir design life sediment storage, dead pool, losses and all the predicted water system demand. A written pumping plan shall be provided that includes the minimum lake level that will be allowed before pumping is initiated, and the recommended pumping rates and quantities. The pumping plan must take into account water quality concerns, such as increased settable solids, turbidity, and microbiological and chemical constituents due to storm runoff events, thereby reducing the amount of available pumping.

3.1.2. Quality.

A sanitary survey and study shall be made of the factors, both natural and manmade, which may affect water quality in the water supply stream, river, lake, or reservoir. The design of a water treatment plant must consider the worst condition that may exist during the life of the facility. Such survey and study shall include, but may not be limited to:

a. Determining possible future uses of lakes or reservoirs;
b. Determining the owner's degree of control over the watershed;
c. Assessing the degree of hazard to the supply posed by agricultural, domestic or industrial contaminant sources including municipal and industrial wastewater treatment plants, and animal feeding operation lagoons, recreational and

residential activities in the watershed and by the accidental spillage of materials that may be toxic, harmful, or detrimental to treatment processes;

d. Obtaining samples over a sufficient period of time to assess the microbiological, physical, chemical, and radiological characteristics of the water;
e. Assessing the capability of the proposed treatment process to reduce contaminants to applicable standards;
f. Considerations of current, wind and ice conditions, and the effect of confluencing streams;
g. Development, to the extent possible, of a watershed protection plan; and
h. Identification of all possible point and non-point sources of contamination discharges.

3.1.3. Structures.

3.1.3.1. Design of intake structures shall provide for:

a. Withdrawal of water from more than one level if quality varies with depth;
b. Separate facilities for release of less desirable water held in storage;
c. Limiting the velocity of flow into the intake structure to a minimum, generally not to exceed 0.5 foot per second, where frazil ice may be a problem;
d. Occasional cleaning of the inlet line;
e. Adequate protection against rupture by dragging anchors, ice, etc.;
f. Ports located above the bottom of the stream, lake or reservoir, but at sufficient depth to be kept submerged at low water;
g. A diversion device capable of keeping large quantities of fish or debris from entering an intake structure, where shore wells are not provided;
h. Where deemed necessary, provisions shall be made for the intake structure to control the influx of zebra mussels or other aquatic nuisances. Specific methods to control zebra mussels shall be approved by the Missouri Department of Natural Resources; and
j. When buried surface water collectors are used, sufficient intake opening area must be provided to minimize inlet headloss. An entrance velocity of 0.1 feet per second is recommended. Particular attention should be given to the selection of backfill material in relation to the collector pipe slot size and gradation of the native material over the collector system;
k. Devices restricting access to intakes.

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3.1.3.2. Raw water pumping wells and transmission mains shall.

a. Have necessary motors and electrical controls and non-submersible pumps and motors located above grade and protected from flooding as required by the department;
b. Be accessible but have devices restricting access to only authorized personnel;
c. Be designed against flotation;
d. Be equipped with removable or traveling screens before the pump suction well;

e. Provide for introduction of chlorine or other chemicals in the raw water transmission main if necessary for quality control;
f. Have valves and provisions for flushing or cleaning by a mechanical device and testing for leaks;
g. Have provisions for withstanding surges and be protected against damage by floating debris where necessary;
h. Not provide water services on raw water transmission mains to residences, farming operations or other retail or wholesale customers without the knowledge and approval of the department and without providing the storage, pressure tanks, pumps and other equipment necessary to adequately supply any services allowed; and
i. Provide meters on any water services on a raw water transmission main.

3.1.3.3. Raw water storage reservoir.

An off-stream raw water storage reservoir is a facility into which water is pumped during periods of good quality and high stream flow for future release to treatment facilities. Raw water storage reservoirs shall be constructed to assure that:

a. Water quality is protected by controlling runoff into the reservoir;
b. Dikes are structurally sound and protected against wave action and erosion;
c. Intake structures and devices meet the requirements of paragraph 3.1.3.1. of this document;
d. Point of influent flow is separated from the point of withdrawal;
e. Separate pipes are provided for influent to and effluent from the reservoir;
f. Raw water sediment is either removed prior to discharge to the reservoir or that multiple reservoirs are provided to allow continued service with a reservoir removed from service for sediment removal; and
g. A bypass line is provided around the reservoir to allow direct pumping to the treatment facilities.

3.1.4. Lakes and reservoirs.

3.1.4.1. Site preparation shall provide, where applicable:

a. Removal of brush and trees to high water elevation;
b. Protection from floods during construction; and
c. Proper abandonment of all wells that will be inundated, in accordance with subparagraph 3.2.5.15. of this document.

3.1.4.2. Construction may require:

a. Approval from the appropriate regulatory agencies of the safety features for stability and spillway design;
b. A permit from an appropriate regulatory agency for controlling stream flow or installing a structure on the bed of a stream or interstate waterway;
c. A permit from the Department of Natural Resources' Water Pollution Control Branch for land disturbance;

d. Restricted access to the dam; and
e. A 300-foot green belt around the perimeter of each water supply lake.

3.1.4.3. Construction shall require:

a. Silt basins and erosion control structures as a part of the lake design. Instead of providing additional lake volume for silt, silt catch basins should be provided;
b. Silt basin design that allows them to be drained and silt routinely removed from the basins; and
c. Sufficient fencing around the lake to prevent access to the lake by livestock

3.1.4.4. Water supply dams.

Water supply dams shall be constructed in accordance with the design guidelines of the Missouri Dam and Reservoir Safety Council regardless of the height of the dam.

3.1.4.5. Recreational uses of public water supply lakes.

Every supplier of water to a public water system must apply for and secure the approval of the department before permitting the use of public water supply impoundments for recreational usage.

a. Regulated recreational activities are permitted when provisions for such activities are included in the original planning, construction, and approval of the impoundment and water treatment facilities.
b. Recreational activities proposed for existing impoundments will be appraised in the light of the effect on the primary purposes of the impoundment, the capability of the water treatment processes, the physical adaptability of the impoundment to the desired recreational use, and the maintenance of public confidence in the water supply.
c. Provisions shall be made for local enforcement of all rules and ordinances governing recreation. Rules must be posted and maintained in legible condition at conspicuous points in the impoundment area. If rules and ordinances cannot be effectively enforced, recreation shall not be provided.

3.1.5. Zebra Mussel Control.

If it is determined that chemical treatment is warranted for the control of zebra mussels:

a. Chemical treatment shall be in accordance with Chapter 5, and shall be acceptable to the department;
b. A spare solution line should be installed to provide redundancy and to facilitate the use of alternate chemicals; and
c. The chemical feeder shall be interlocked with plant system controls to shut down automatically when the raw water flow stops.

3.2. Groundwater.

A groundwater source includes all water obtained from dug, drilled, bored, driven wells and infiltration lines.

3.2.1. Quantity.

3.2.1.1. Minimum capacity.

The total developed groundwater source capacity shall equal or exceed the design maximum day demand.

3.2.1.2. Number of sources.

a. Because wells drilled into unconsolidated formations must be routinely removed from service for cleaning and redevelopment, all water systems served by these wells shall have more than one well and shall be capable of meeting maximum day demand with the largest producing well out of service.

b. Public drinking water systems serving 500 or more people shall have more than one well and shall be capable of meeting design average day demand with the largest producing well out of service or an alternate approved source of water capable of meeting the design or actual average day demand.

c. Public drinking water systems serving less than 500 people should have more than one well, or an alternate source of supply, such as an interconnection with another water system, and should be capable of meeting design average day demand with the largest producing well out of service. In determining the minimum number of wells needed, the supplier of water should consider such factors as the amount of system storage, the critical nature of businesses being served by the water system (for example, hospitals), and the amount of water needed.

3.2.1.3. Auxiliary power.

a. When power failure would result in cessation of minimum essential service, sufficient power should be provided to meet average day demand through portable or in-place auxiliary power.

b. When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, design shall assure that the pre-lubrication is provided when auxiliary power is in use.

3.2.2. Quality

3.2.2.1. Water Quality.

A study shall be made of the factors, both natural and man-made, which may affect water quality in the well and aquifer. The design of a water treatment plant, or treatment at the well house, must consider the worst condition that may exist during the life of the facility. Such survey and study shall include, but may not be limited to obtaining samples over a sufficient period of time to assess the microbiological and physical characteristics of the water including dissolved gases, chemical, and radiological characteristics.

3.2.2.2. Microbiological quality.

a. Tools, pumps, pipe, gravel pack material, drilling equipment and water used during drilling should be treated with 200 milligrams per liter chlorine solution. Wells should be tested for any signs of iron or sulfur bacteria contamination after drilling. If possible, the water in the aquifer should be tested before drilling a production well to determine if iron or sulfur reducing bacteria are naturally present. If iron or sulfur reducing bacteria is found, facilities shall be installed to provide for routine treatment of the well, continuous chlorination to prevent bacteria growth in the distribution system and pigging of raw water lines where appropriate

b. Disinfection of every new, modified or reconstructed groundwater source shall be:
    1. In accordance with the latest AWWA Standard C-654;
    2. Provided after completion of work if a substantial period elapses prior to test pumping or placement of permanent pumping equipment;
    3. Provided after placement of permanent pumping equipment; and
    4. Provided any time the pump or column pipe is removed or replaced.

c. After disinfection, one or more water samples shall be submitted to a laboratory certified by the department for microbiological analysis and the results reported to the department prior to placing the well into service**.** Before placing the well in service, water samples for microbiological analysis shall test absent for coliform bacteria on two consecutive days from wells drilled in consolidated formations unless the water will be continuously disinfected with the required contact time before being dispensed. Water from wells that are provided with continuous disinfection and the required contact time before being dispensed is not required to meet the above microbiological standards. Microbiological analysis of water samples from these wells shall be done to determine the degree and extent of microbiological contamination present but the presence of coliform bacteria is not grounds for rejection of these wells. However, tests for more than total coliform bacteria should be considered.

3.2.2.3. Physical and chemical quality.

a. Every new, modified, or reconstructed groundwater source shall be examined for applicable physical and chemical characteristics by tests of a representative sample in a laboratory certified by the department.

b. Samples shall be collected at the conclusion of the test pumping procedure and examined as soon as practicable (within the specified holding period).

c. Field determinations of physical and chemical constituents or special sampling procedures may be required by the department.

3.2.2.4. Radiological quality.

Each new or modified groundwater source shall be examined for radiological activity as required by the department.

3.2.3. Location.

3.2.3.1. Well location.

a. Prior to design and construction, the Department of Natural Resources Regional Office serving the area in which the well will be located shall be consulted regarding a proposed well location as it relates to the required separation between existing and potential sources of contamination and groundwater development.

b. The Department of Natural Resources' Water Resource Center shall be consulted prior to design and construction regarding a proposed well location as it relates to required well depth and casing depth, for consolidated formations.

c. Prior to construction, sufficient information shall be submitted to the department to determine if adequate spacing will be provided between the proposed well or well field and existing active public water supply wells. The department may require that pump tests be done on the closest active existing well. Pump test data submitted shall be acceptable to the department and pump tests shall be performed in accordance with section 3.2.4 of this guide. Existing pump tests data may be used if the methods and quality of the data are acceptable to the department. Where multiple wells that will be pumped at the same time are proposed in a new area, test holes should be drilled and pumped simultaneously to determine the spacing necessary to prevent interference between wells.

3.2.3.2. Isolation standards.

a. Unless the geology and aquifer hydraulics dictate greater or lesser distances, or unless the department approves a lesser distance based on the engineering report, acceptance of the well site, for new wells, shall be based on compliance with the radii in Table 2.

Table 3 – New Well Isolation Radii

Source of Possible Contamination	Minimum Isolation Radius
Wastewater treatment plants, wastewater lagoons, chemical storage, landfills, any liquid petroleum storage tanks, any surface or subsurface wastewater and solid waste disposal fields	300 feet
Manure storage area, unplugged abandoned well, graves, sewage pumping station, building or yard used for livestock or poultry, privy, cesspool, or other contaminants that may drain into the soil	100 feet
Sanitary sewer lines, existing wells, pits sumps or holes, propane tanks, septic tanks, lakes or streams	50 feet
The right-of-way of federal, state, or county road	10 feet

b. (1) The owner of the well should control or own all the land within an isolation radius to the extent necessary to maintain minimum distances

from potential sources of contamination after the well is constructed.
(2) The owner of the well should adopt a wellhead protection program and should encourage adjacent landowners to adopt voluntary restrictions on land use.
(3) Where legal authorities (such as a city council or county zoning authority) exist to provide ordinances, covenants, zoning, or other legally binding restrictions, the owner of the well should make every feasible effort to obtain legally binding restrictions to control or own all the land within an isolation radius to the extent necessary to maintain minimum distances from potential sources of contamination after the well is constructed.

c. Wells in unconsolidated formation may require greater isolation radii.
d. A well shall be located at least three feet horizontally from a building or any projection, except for a pump house.
e. No well shall be located within 15 feet of an overhead electric distribution line or 25 feet from an electric transmission line that is in excess of 50 kilovolts (kV) except for the underground electrical service line in the vicinity of an existing well or proposed well. Where there is a question of the voltage in an electric line, the 25-foot distance should be observed, or where less distance is required the utility company should be consulted for their recommendation for safe distances.

3.2.3.3. Other site location and security considerations.

a. The well shall be so located that the site will meet the requirements for sanitary protection of water as well as protection against fire, flood, vandalism, terrorist acts, or other hazards.
b. The top of the well shall be elevated to a minimum of four feet above the 100-year return frequency flood elevation or four feet above the highest historical flood elevation, which ever is higher, or protected to such elevations.
c. The top of the upper terminal of the well shall be readily accessible to operating and maintenance personnel at all times unless the overall system design allows the well to be out of service for the period of inaccessibility.
d. Wells elevated more than four feet above the ground shall be provided with work platforms of sufficient size to provide for safe access to the well head for maintenance and testing. Access to these platforms shall be by stairs or ships ladders.
e. For elevated wells, access shall not be by a trap door or open hole in the floor of a well house or well platform.
f. Well houses and enclosed platforms are considered raw water pumping stations and must be designed according to chapter 6 of this guide.
g. The area around the well shall be graded to lead surface water drainage away from the well.

3.2.4. Testing and records.

Geological data and the results of all pump tests shall be submitted in duplicate to the department as a part of the submittal to obtain a Final Approval of Construction prior to placing the well in service. State law 640.115(1) prohibits the use of any source of supply without a written permit of approval issued to the continuing operating authority by the department and the Final Approval of Construction acts as that written permit for water sources.

Drillers of public water supply wells shall comply with the Missouri well construction rules and shall submit certification and registration reports on forms provided by the department within 60 days after drilling the well.

3.2.4.1. Yield and drawdown tests.

Properly conducted pumping tests are necessary to determine the drawdown characteristics of newly drilled wells and also to determine the hydrologic characteristics of the aquifers from which the wells produce. Most standard aquifer evaluation methods require drawdown data collected from a well being pumped at a constant rate, or from a nearby observation well that is similar in depth and construction to the pumped well. Water discharged during a pumping test shall be conducted to the nearest surface water body, storm sewer or ditch in a manner that prevents property damage and that prevents recirculation of discharged water into the aquifer being pumped.

3.2.4.1.1. For all wells in **consolidated** formations and unconsolidated formations greater than 300 feet deep, tests shall:

a. Be performed on every production well 8 inches in diameter or larger. Pumping tests are recommended but are not required for wells smaller in diameter than 8 inches;
b. Have the test methods clearly indicated in specifications;
c. Be a constant rate pumping test using the permanent pump designed for the well or a test pump that produces at least 100 percent of the designed production of the well with the pump test lasting at least 24 hours or be a constant rate pumping test using a pump able to produce at least 1.5 times the designed production of the well pumped with the pump test lasting no less than eight (8) hours if drawdown has stabilized for at least two hours. If the drawdown has not stabilized, the test shall continue for at least 24 hours;
d. Hold the pumping rate as constant as possible. If during the pumping test it is found that the pumping rate must be decreased more than five percent from the initial pumping rate to prevent the pump from breaking suction, then the pumping test shall be terminated and water level in the well allowed to recover to static water level before the full pumping test is repeated at a lowered pumping rate;
e. Measure the pumping rate using an accurate rate-of-flow meter, venturi meter, or using a calibrated orifice plate and manometer;
f. Measure the pumping rate and record the results every 10 minutes

during the first hour of the pumping test and at 30 minute intervals thereafter;

g. Measure the water level in the well and in any observation wells as accurately as possible using an electronic water-level indicator, pressure transducer, air line and pressure gauge, or other device capable of accurately measuring depth-to-water in the well;

h. Measure the pumping water level during the test according to the following schedule:

0 to 10 minutes – every minute
10 to 50 minutes – every 5 minutes
50 to 90 minutes – every 10 minutes
90 to 180 minutes – every 30 minutes
180 minutes to end of test – every 60 minutes

i. Collect recovery data when pumping is ended using the same schedule shown in subsection “h” above for a minimum of 6 hours or until water level recovers to pre-pumping static water level, whichever occurs first;

j. Provide the following pumping test data to the Water Resources Center within 14 days after completion of the pumping test;

1. Well owner name
2. Well location (section-township-range numbers or latitude-longitude and country
3. Test pump capacity vs. head characteristics
4. Static water level
5. Depth of test or permanent pump setting
6. Pumping rate
7. Time and pumping water level data collected according to the schedule in subsection “h” above
8. Time and recovery water level data collected according to the schedule in subsection “h” above

k. If desired, be a variable rate or step-test pumping test in addition to the required constant rate test.

3.2.4.1.2. For wells in **unconsolidated** formations less than 300 feet deep, yield and drawdown tests must produce the data necessary to determine the capacity of the well, aquifer characteristics, well efficiency, pumping rates, required distances between wells, pump installation depth settings and other factors that will be of value in the long term operation and maintenance of the well. These comprehensive tests require a minimum of one or two observation wells located 100 to 300 feet from the production well and at the same depth. When wells are drilled in new areas where characteristics and extent of the formation is unknown a 7-day pump test should be performed. Yield and drawdown tests shall:

a. Be done on every production well after construction but before placement of the permanent pump;

b. Be done using a pump with a capacity, at maximum anticipated draw-down, at least 1.5 times the quantity anticipated. Bailing, air blowing or air lifting shall not be used;

c. Be done using an accurate rate-of-flow meter, venturi meter, or using a calibrated orifice plate and manometer;

d. Provide for measurement of water levels using an electronic water-level indicator, pressure transducer, air line and pressure gauge, or other device capable of accurately measuring depth-to-water in the well;

e. Be done according to one of the following methods:

1. The Variable Rate Method: This method is done by setting the pump at the lowest producing zone and pumping at 1.5 times the design rate of the well until the pump breaks suction. If the pump does not break suction for a period of 24-hours, the test shall be completed as a continuous rate test. If the pump breaks suction, the rate shall be slowly decreased until the pumping level stabilizes approximately two feet above the pump intake for at least five minutes. Then the pumping rate shall be decreased 5% and the well pumped until the pumping level stabilizes for one hour. The pumping level shall be measured according to the following schedule:
   - 0 to 10 minutes - every minute;
   - 10 to 50 minutes - every 5 minutes;
   - 50 to 90 minutes - every 10 minutes;
   - 90 to 180 minutes - every 30 minutes;
   - 180 minutes to the end of the test - hourly.

   The discharge rate and drawdown thus established shall then be maintained for at least four hours. This pumping rate shall be considered the available production rate of the well and the observed pumping level during the test shall be considered the production pumping level. On completion of the pumping, recovery measurements shall be made according to this same schedule until full recovery is reached or the level stabilizes for at least four hours. The static water level shall be established before the start of the pumping test;
2. The Constant Rate Method: This method is done by pumping the well at a discharge rate that is 1.5 times the design rate of the well with the test pump intake set at least five feet below the estimated lowest pumping level. Discharge shall be maintained within plus or minus 5% percent of this flow and shall be checked every ten minutes during the first hour of the test and at 30 minute intervals thereafter. The well shall be pumped for 24 hours or until the pumping level stabilizes for four hours. The static water level shall be established before the start of the pumping test. The pumping level shall be measured according to the following schedule:
   - 0 to 10 minutes - every minute;

10 to 50 minutes - every 5 minutes;
50 to 90 minutes - every 10 minutes;
90 to 180 minutes - every 30 minutes;
180 minutes to the end of the test - hourly.

On completion of the pumping, recovery measurements shall be made according to this same schedule until full recovery is reached or the level stabilizes for at least four hours;

3. The Step Continuous Composite Method: This method is done by setting the pump at the lowest producing zone and pumping the well at rates ½, ¾, 1, and 1½ times its design capacity. Discharge shall be maintained within plus or minus 5% percent of the designated flow. For each pumping rate, discharge shall be checked at 10-minute intervals during the first hour of the test and 30-minute intervals thereafter. The static water level shall be established before the start of the pumping test. The pumping level shall be measured according to the following schedule:

0 to 10 minutes – every minute
10 to 50 minutes – every 5 minutes
50 to 90 minutes – every 10 minutes
90 to 180 minutes – every 30 minutes
180 minutes to the end of the test – hourly.

At each rate step, the well shall be pumped until the pumping level stabilizes for at least four hours or the pump breaks suction. Water level in the well shall be allowed to recover to static or stabilize for one hour after each pumping step. After each increase in pumping rate, the above measurement schedule shall be repeated. On completion of the pumping, recovery measurements shall be made according to this same schedule until full recovery is reached or the level stabilizes for at least four hours; or

4. Aborted Test: Whenever continuous pumping at a uniform rate is specified, failure of the pump operation for a period greater than one percent of the elapsed pumping time shall require suspension of the test until the water level in the pumped well has recovered to its original level. If the water level does not recover to its original level, pump testing can resume if three successive water level measurements spaced 20 minutes apart show no rise in level; and

g. Provide to the department written records and graphic evaluations of all times, static water levels, pumping rates, pumping water levels, drawdown, and water recovery rates and levels measured.

3.2.4.2. Geological data.

a. Geological data shall be determined from samples collected at five-foot intervals and at each pronounced change in formation.
b. For wells drilled in consolidated material, geological data shall be recorded and samples submitted to the Water Resources Center.
c. For wells drilled into unconsolidated material, a detailed driller's log of all

wells and test holes associated with the public well shall be submitted in duplicate to the Public Drinking Water Branch.

d. Geological data shall be supplemented with information on drill hole diameters and depths, assembled order of size and length of casing, screens and liners; grouting depths; formations penetrated, water levels, and location of any blast charges.

3.2.5. General well construction.

3.2.5.1. Minimum protected depths.

Minimum protected depths of drilled wells shall provide watertight construction to such depth as may be required by the department.

3.2.5.2. Special conditions for wells drilled into consolidated formations.

The depth of the permanent casing will be determined from the examination of drill cuttings by the Geological Survey and Resource Assessment Division.

3.2.5.3. Special conditions for wells drilled into unconsolidated formations

a. If clay or hard pan is encountered above the water bearing formation, the permanent casing and grout shall extend through such materials but shall not extend any less than 20 feet below the original ground elevation.

b. If a sand or gravel aquifer is overlaid only by permeable soils, the permanent casing and grout shall extend to at least 20 feet below the original or final ground elevation, whichever is lower.

c. If a temporary or a surface casing is used, it shall be completely withdrawn at the time the well is grouted. Failure to completely withdraw the temporary casing or temporary surface casing in wells less than 300 feet deep is grounds for rejection of the well.

d. If a pitless unit is used for a well with less than 100 feet of casing, the outer casing shall not be cut off below the pitless unit. The discharge piping from the pitless unit shall extend through the outer casing and the annular space between the outer casing and the drill hole. The hole where the discharge pipe from the pitless unit extends through the outer casing shall be sealed water tight with a mechanical device or welding. Neat cement grout shall be placed in the annular space between the outer casing and the drill hole and around the discharge piping from the pitless unit to final ground level.

e. In wells drilled in flood plains where a berm is constructed to elevate the well site, the permanent outer casing shall extend at least 20 feet below the original ground surface and be grouted to the final ground elevation.

3.2.5.4. Drilling fluids and additives shall:

a. Not impart any toxic substances to the water or promote bacterial contamination;

b. Be acceptable to the department;

c. Shall be capable of being removed from the drill hole and formation so that they do not retard the capacity of the well; and

d. Use water for preparation that will not contaminate the aquifer.

3.2.5.5. Surface or temporary casing.

Surface or temporary casing used for construction shall be capable of withstanding the structural load imposed during its installation and removal. Surface or temporary casing shall be removed during or prior to grouting or it shall be grouted in place when set according to 3.2.5.11. If the temporary or surface casing cannot be withdrawn, the driller must contact the design engineer to apply to the department for approval of a method to finish the well. Any approved modifications to the well design due to unusual conditions must be reflected in as-built drawings submitted to the department. The engineer of record must submit as-built plans or plans of record of the well that shows all casings and the method with which they were sealed before the well can be approved as a water supply source.

3.2.5.6. Permanent steel casing pipe shall:

a. Be new pipe meeting AWWA Standard A-100, or ASTM or API specifications for water well construction;
b. Have minimum weights and thickness indicated in Table 5;
c. Have additional thickness and weight if minimum thickness is not considered sufficient to assure the reasonable life expectancy of a well;
d. Be capable of withstanding forces to which it is subjected; and
e. Have full circumferential welds or threaded coupling joints.

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3.2.5.7. Gravel pack material.

a. Gravel pack materials shall:
   1. Be sized based on sieve analysis of the formation and copies of sieve analyses of the water bearing formation and of the proposed gravel pack shall be submitted to the department for approval before the installing the gravel pack;
   2. Be well-rounded particles, 95 percent siliceous material, that are smooth and uniform, free of foreign material, properly sized, washed and then disinfected immediately prior to or during placement;
   3. Have an average specific gravity of not less than 2.5;
   4. Have uniformity coefficient not to exceed 2.5;
   5. Have a gravel pack-to-formation sand ratio within the range of 6:1 to 4:1; and
   6. Be disinfected with at least a solution of 200 milligrams per liter chlorine, just before installation.
b. Gravel pack.
   1. Gravel pack shall be placed in one continuous operation.
   2. Gravel pack shall be placed in a manner that prevents segregation and gradation during placement.
   3. The annular space between the well screen and the hole shall be at least four inches to allow proper placement of gravel pack.
   4. Gravel refill pipes, when used, shall be Schedule 40 steel pipe

incorporated within the pump foundation and terminated with screwed or welded caps at least 12 inches above the pump house floor.

5. Gravel refill pipes located in the grouted annular opening shall be surrounded by a minimum of 1 ½ inches of grout.
6. Gravel pack shall extend at least 2 ½ times the largest diameter of the well above the highest well screen.
7. Protection from leakage of grout into the gravel pack or screen shall be provided.
8. Permanent inner casing and outer casings shall meet requirements of subparagraph 3.2.5.6.

3.2.5.8. Packers.

In general, the use of packers should be avoided. Telescoping wells and well casings shall be justified to and approved by the department prior to construction, but in general should be avoided. The well screen should be threaded or welded to the permanent casing with the appropriate transition fitting. When used, packers shall be of material that will not impart taste, odor, toxic substance or bacterial contamination to the well water. Lead packers shall not be used.

3.2.5.9. Screens shall:

a. Be constructed of stainless steel;
b. Have size of openings based on sieve analysis of formation and/or gravel pack materials. Copies of sieve analyses of the water bearing formation and of the proposed gravel pack shall be submitted to the department for approval before the size of the screen is specified;
c. Have sufficient diameter and length to provide adequate specific capacity and a lower entrance velocity not to exceed 0.1 foot per second. A lower entrance velocity is recommended for water of significant incrustation potential;
d. Be installed so that the pumping water level remains above the screen under all operating conditions;
e. Where applicable, be designed and installed to permit removal or replacement without adversely affecting watertight construction of the well;
f. Be provided with a bottom plate or washdown bottom fitting of the same material as the screen; and
g. Be capable of resisting the column and tensile loads and the collapse pressures imposed during installation and well development and imposed by the external geological forces.

3.2.5.10. Plumbness and alignment requirements.

a. Every well shall be tested for plumbness and alignment in accordance with the latest edition of AWWA Standard A-100.
b. The test method and allowable tolerance shall be clearly stated in the specifications.

c. If the well fails to meet these requirements, it may be accepted by the engineer, after consultation with the department, if it does not interfere with the installation or operation of the pump or uniform placement of grout.

3.2.5.11. Grouting requirements.

a. All permanent well casings shall be surrounded by a minimum of 1½ inches of grout to the depth required by the department. Grouting consists of filling the annular space between the permanent casing and the drill hole with impervious material. Grouting is necessary to protect water-bearing aquifers from contamination, to prevent unwanted water movement between aquifers and to preserve or protect the hydraulic response of the water producing zones.

b. Grout materials shall consist of Portland cement conforming to the latest AWWA Standard and water, with not more than six gallons of water per sack (94 pounds) of cement

c. Additives may be used to increase fluidity of grout materials or to bridge voids, subject to prior approval by the department.

d. Application.

   1. Sufficient annular opening shall be provided to permit a minimum of 1 1/2 inches of grout around permanent casings, including couplings.
   2. Prior to grouting through creviced or fractured formations, bentonite or similar materials may be added to the annular opening, in the manner indicated for grouting.
   3. Before placing the grout, water or other drilling fluid shall be circulated in the annular space sufficient to clear obstructions.
   4. When grouting a well, one of the following methods shall be used:
      i. The Positive-Placement Interior Method (grout pipe): When the annular opening is less than three inches (the diameter of the drill hole is less than six inches larger than the casing diameter), grout shall be installed using the positive-placement interior method. This method involves pumping the grout through a pipe inside the well casing. Either an expandable or drillable plug shall be installed at the bottom of the well casing, and the grout pipe shall extend through this plug. Then grout shall be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled. If the grout does not reach the surface, the driller shall wait at least 24 hours and then determine the elevation of the top of the grout. The appropriate Department of Natural Resources Regional Office shall be contacted for approval of the method used to complete grouting of the well by using the tremie method;
      ii. The Positive-Displacement Interior Method (Casing): When the annular opening is less than three inches (the diameter

of the drill hole is less than 6-inches larger than the casing diameter), grout shall be installed using the positive-displacement interior method. The casing can be used as the grout conduit if the grout is pumped under pressure through the casing and up the annular space of the drill hole. A device shall be installed on the top of the casing that contains a drillable plug and a valved fitting below the plug and another valved fitting above the plug. Provisions for holding the plug in place before and during grouting shall be part of the grouting device. The device, plug and its fittings shall be capable of withstanding the pressures generated by pumping the grout and water. Grout shall be pumped through the fitting below the plug until the volume of grout pumped exceeds the calculated volume of the annular space between the drill hole and the permanent casing by one fourth to one third. Then the lower fitting is shut off and water is pumped through the fitting above the plug to drive the plug to the bottom of the casing and the grout out of the bottom of the casing and into the annular space. If the grout does not reach the surface, the driller shall wait at least twenty-four (24) hours and then determine the elevation of the top of the grout. The appropriate Department of Natural Resources' Regional Office shall then be contacted for approval to complete grouting of the well by tremie method;

iii. The Positive-Placement Exterior Method: When the annular opening is three or more inches (the diameter of the drill hole is six or more inches larger than the casing diameter) and less than 300 feet in depth, grout may be placed by the positive-placement exterior method. This method requires pumping grout through a grout pipe installed in the annular opening. The maximum diameter of the grout pipe shall be at least 1½-inches smaller than the annular opening. The grout shall be placed to the bottom of the annular opening in one continuous operation until the annular opening is filled. The grout pipe shall be raised as the grout is placed but the discharge end of the grout pipe must be submerged in the placement grout at all times until grouting is complete. The grout pipe shall be maintained full, to the surface, at all times until grouting is complete. In case of interruption of grouting operations, the grout pipe must be removed from the drill hole and all air and water displaced from the grout pipe and the pipe flushed clean with clear water. After the grout pipe is cleaned, it may be placed in the drill hole and grouting resumed; or

iv. The Tremie Method: When the annular opening is four or more inches **(**the diameter of the drill hole is eight or more inches larger than the casing diameter) and less than 100 feet in depth, grout may be placed by gravity through a tremie pipe. The tremie pipe shall be installed to the bottom of the annular opening and the grout placed in one continuous operation until the annular opening is filled. The tremie pipe shall be raised as the grout is placed but the discharge end of the pipe must be submerged in the placement grout at all times until grouting is complete. The tremie pipe shall be maintained full, to the surface, at all times until grouting is complete. The maximum diameter of the tremie pipe shall be at least 1½-inches smaller than the annular opening.

5. After grouting is applied, work on the well shall be discontinued for at least 72 hours or until the grout has set properly.

e. Guides.

1. The casing shall be provided with sufficient guides welded to the casing to center the casing in the drill hole, prevent displacement of the casing and still permit unobstructed flow and uniform thickness of grout.
2. Centering spacer guides shall be provided at the bottom, at the top, and along the entire length of the casing at no more than 105 feet apart.

3.2.5.12. Upper terminal well construction.

a. Permanent casing for all groundwater sources shall project at least 12 inches above the pump house or well platform floor or concrete apron surface and at least 18 inches above final ground surface.

b. Where a vertical turbine pump is provided for the well, the pump house must have forced ventilation of at least six changes of air per hour.

c. For gravel wall wells and alluvial wells with less than 100 feet of permanent casing, in which grout has not been placed between the casings, all casings must extend at least 12 inches above the pump house or well platform floor or concrete apron surface and at least 18 inches above final ground surface.

d. For gravel wall wells that have inner and outer casings and wells where the surface casing is left in place using submersible pumps, the inner or production casing shall extend at least 6 inches above the outer casing.

e. The top of all well casings left in place at sites subject to flooding shall terminate at least four feet above the 100 year level or the highest known flood elevation, whichever is higher, or as the department directs.

f. The upper terminal shall be constructed to prevent contamination from entering the well.

g. Where items such as water discharge piping, electric wiring, airlines, well vents and so forth protrude through the upper terminal, the connections to the upper terminal shall be mechanical or welded connections that are water tight. Silicon or other caulking does not meet this requirement.

h. All electrical installations shall be performed and maintained in accordance with nationally accepted electric codes. A permitted well installation contractor or pump installation contractor must perform all electric wiring which impacts the operation of the pump or pumping system. This includes wiring from the pump to the control boxes to the main power supply such as the breaker box in a well house.

3.2.5.13. Development.

a. Practically all drilling methods cause compaction of unconsolidated materials in an annulus of variable thickness about a drill hole. In consolidated formations, similar compaction may occur in some poorly cemented rocks. In addition, fines are driven into the wall of the hole, drilling mud invasion may occur, and a mud cake may form on the wall of a hole. Proper well development breaks down the compacted drill hole wall, liquefies jelled mud, and draws it and fines into the well where they can be removed. Therefore, every well should be developed and the well construction specifications should include the well development methods to be used.

b. Every well drilled into an unconsolidated formation shall be developed by surging and bailing or surging and pumping. The surging shall be done using a single or double solid or valved surge block. Surging shall start at the lowest screen in the well and proceed upwards. Pumping shall be done through the surge block by incorporating suction pipe in the fabrication of the block and shall be done simultaneously with surging. Other methods of development may be considered on a case by case basis and must be specifically approved by the department before use.

c. The approval of the department is required before doing any chemical washing of a well with mud dispersing agents, acids or other chemicals.

d. Development shall continue until the maximum specific capacity is obtained from the completed well.

e. The specifications shall include a detailed description of the well development methods to be used.

f. Any redevelopment or rehabilitation shall require prior approval from the department.

3.2.5.14. Capping requirements

a. A continuously welded metal plate or a threaded cap is the preferred method for capping a well. For gravel wall wells that have inner and outer casings and wells where the surface casing is left in place, a continuously welded metal plate shall be provided to cap the area between the two casings and provide a water tight seal. As an alternative, the space between the two casings may be sealed with at least one foot of non-shrink grout to the top of the outer or surface casing**.**

b. A properly fitted, firmly driven, solid wooden plug is the minimum acceptable method of temporarily capping a well until pumping equipment is installed.

c. At all times during the progress of work, the contractor shall provide protection to prevent tampering with the well or entrance of foreign materials.

3.2.5.15. ***Well plugging.***

All well plugging shall conform to appropriate standards developed by the Missouri Department of Natural Resources.

3.2.6. Well pumps, discharge piping and appurtenances.

3.2.6.1. Line shaft pumps.

a. Wells equipped with line shaft pumps shall:
   1. Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least one-half inch into the pump base; and
   2. Have the pump foundation and base designed to prevent water from coming into contact with the joint.

b. Avoid the use of oil lubrication. For existing wells with oil-lubricated pumps and new wells where oil lubrication cannot be avoided, only food grade vegetable oil or mineral oil approved by the ANSI/NSF shall be used.

3.2.6.2. Submersible pumps. Where a submersible pump is used:

a. The top of the casing shall be effectively sealed against the entrance of water under all conditions, including the vibration or movement of conductors or cables;

b. The electric cable from the pump control panel to the well shall be installed in electric conduit and in a manner that it does not create a fall or tripping hazard; and

c. The electrical cable shall be firmly attached to the riser pipe at 20- foot intervals or less.

3.2.6.3. Discharge piping.

All plumbing or water supply distribution from the well to the point of entry hookup shall be installed and maintained in accordance with nationally accepted plumbing codes. A permitted well installation contractor or pump installation contractor must perform all plumbing which impacts the distribution of water from its source to the point of entry inside or outside of the well structure, well-house, or building.

a. The discharge piping from the well head to the system shall:
   1. Not be piping that may impart contaminants into the water;
   2. Galvanized steel or iron pipe shall be galvanized with a zinc coating that does not contain leachable levels of lead or other contaminants and the pipe must meet ANSI/NSF Standards 60/61.
   3. Be flanged and bolted mechanical joint, threaded or fusion welded pipe;

2. Not be solvent welded plastic if the pipe is greater than 2-inches in diameter**;**
3. Where steel, iron or solvent welded plastic is used, be no less than schedule 80;
4. Where plastic pipe is used, meet ANSI/AWWA Standard C900 or C909 for polyvinyl chloride pipe; ANSI/AWWA Standard C 901, C905 or C906 for polyethylene or ANSI/AWWA Standard C950 for fiberglass pipe;
5. Where polyethylene plastic pipe is used, have a standard dimension ratio (SDR) no greater than 11;
6. Be designed to minimize friction loss;
7. Have the control valves and appurtenances located in a pump house and above the pump house floor when an above-ground discharge is provided;
8. Be protected against the entrance of contamination;
9. Be equipped with a check valve, a shutoff valve, a pressure gauge, and a totaling water meter;
10. Have valves upstream and downstream of the water meter to allow it to be easily removed for maintenance;
11. Be equipped with a smooth nosed sampling tap located at a point where positive pressure is maintained, but before any treatment chemicals are applied. The sample tap must be at least 18-inches above the floor to facilitate sample collection. Hose bib faucets shall not be used;
12. Be equipped with a sampling tap located downstream of any chemical application points to allow sampling for dose control;
13. Where applicable, be equipped with an air release and vacuum relief valve located upstream from the check valve; with exhaust and relief piping terminating in a down-turned position at least 18 inches above the floor and covered with an 18-mesh corrosion resistant screen;
14. Be valved to permit test pumping and control of each well;
15. Have all exposed piping, valves and appurtenances protected against physical damage and freezing;
16. Be properly anchored to prevent movement and be properly supported to prevent excessive bending forces;
17. Be protected against surge or water hammer; and
18. Be constructed so that it can be easily disconnected from the well or well pump to allow the well pump to be pulled for maintenance.

b. The discharge piping should be provided with a means of pumping to waste, but shall not be directly connected to a sewer.

c. For submersible, jet and line shaft pumps, the discharge, drop or column piping inside the well shall:
1. Not be piping that may impart contaminants into the water;
2. Galvanized steel or iron pipe shall be galvanized with a zinc coating that does not contain leachable levels of lead or other contaminants

and the pipe must meet ANSI/NSF Standards 60/61. Any lubricants, fittings, brackets, tape or other appurtenances shall meet ANSI/NSF Standards 60/61 to prevent the imparting of toxins into the water;

3. Be capable of supporting the weight of the pump, piping, water and appurtenances and of withstanding the thrust, torque and other reaction loads created during pumping. The actions of fatigue from repeated starting and stopping of the pump shall be considered when choosing a pipe and fittings. Preferred pipe is epoxy coated ductile iron, black iron or steel pipe that is equivalent to schedule 80 or greater;
4. Where threaded piping and couplings are used, have threads and couplings designed to support the weight of the pump, piping, water and appurtenances and to withstand the thrust, torque and other reaction loads created during pumping;
5. Where well plumbness is an issue, be fitted with guides or spacers to center the piping and well pump in the casing;
6. Where plastic coated woven high tensile strength polyester hose is used, obtain a variance from the wellhead protection section prior to installation;
7. Where plastic coated woven high tensile strength polyester hose is used, be specifically manufactured for use as submersible pump drop pipe. With this product soft start or variable speed pumps or torque arrestors shall be installed;
8. Where plastic coated woven high tensile strength polyester hose is used, have bands, brackets or connectors specifically designed to attach power cables and air lines to the hose;
9. Where plastic coated woven high tensile strength polyester hose is used, not exceed manufacturers' recommendations on maximum load capacity, working pressure and pump setting;
10. Where plastic pipe is used, meet ANSI/AWWA Standard C900 or C909 for polyvinyl chloride pipe; ANSI/AWWA Standard C901, C905 or C906 for polyethylene pipe or to the pipe joints and connections of the plastic pipe to any other type of pipe or fitting within the well to assure that they will support the weight of the pump, piping, water and appurtenances and withstand the thrust, torque and other reaction loads created during pumping;
11. Where polyvinyl chloride pipe is used, be no less than Schedule 120 pipe;
12. Obtain a variance from the wellhead protection section before installing high density polyethylene plastic pipe;
13. Where high density polyethylene plastic pipe is used, have a standard dimension ratio (SDR) no greater than (9) nine;
14. Where high density polyethylene (HDPE) plastic pipe is used, be either one continuous length of pipe with no joints or be heat fusion jointed pipe done by a certified heat fusion technician. High density polyethylene pipe shall be chosen such that the long term

(ten year) allowable tensile strength exceeds the weight of the water, pipe, pump, valves, fittings and other appurtenances without material creep; and

15. Not be corrugated flexible plastic pipe of any type.

3.2.6.4. *Pitless well units.*

A pitless unit is a commercially manufactured assembly that extends the upper end of the well production casing to its upper terminal, prevents the entrance of contaminants into the well, conducts water from the well, prevents water from freezing and provides full access to the well for maintenance. Pitless well adapters are not allowed.

a. The department must be contacted for approval of specific applications of pitless units.
b. Pitless units shall:
    1. Be shop-fabricated from the point of connection with the well casing to the unit cap or cover;
    2. Be threaded or welded to the well casing;
    3. Be of watertight construction throughout;
    4. Be of materials and weight at least equivalent and compatible to the casing;
    5. Have field connection to the lateral discharge from the pitless unit of threaded, flanged or mechanical joint connection; and
    6. Terminate at least 18 inches above final ground elevation, four feet above the 100-year flood level, or the highest known flood elevation whichever is higher.
c. The design of the pitless unit shall make provision for:
    1. Access to disinfect the well;
    2. Access for water level testing equipment or pneumatic lines with the necessary gauges;
    3. A properly constructed casing vent that meets the requirements of this document;
    4. Facilities to measure water levels in the well as specified in this document;
    5. A sanitary well cap at the upper terminal of the unit that is certified as water tight by the Water Systems Council to prevent the entrance of contamination;
    6. A contamination-proof entrance connection for electrical cable;
    7. An inside diameter as great as that of the well casing; up to and including casing diameters of 12 inches in order to facilitate work and repair on the well, pump or well screen; and
    8. At least one check valve within the well casing or in compliance with requirements of the department.
d. If the connection to the casing is to be welded in the field, shop-assembled unit must be designed specifically for field welding to the casing. The only field welding permitted will be that needed to connect a pitless unit to the casing.

Deleted: seal

e. For wells drilled into consolidated formations and unconsolidated wells with more than 100 feet of permanent casing, the surface casing or outer casing may be cutoff below the pitless unit if the casing was grouted in place according to section 3.2.5.11. The annular space between the pitless unit and the drill hole shall be filled with cement grout or concrete to the ground surface. The portion of the discharge pipe within the drill hole shall be completely surrounded with cement grout or concrete.

3.2.6.5. Casing vent.

Provisions shall be made for venting to the atmosphere the well casing that houses the well pump. The vent pipe shall be installed into the side of the casing and shall terminate in a downturned position at or above the top of the casing or pitless unit with the opening covered with an 18 mesh, corrosion resistant screen. The pipe connecting the casing to the vent shall be of adequate size to provide rapid venting of the casing but shall not be smaller than 1.5-inches in diameter.

3.2.6.6. Water level measurement.

a. Provisions shall be made for periodic measurement of water levels in the completed wells,
b. Where pneumatic lines are used, water level measuring equipment and accessories shall be provided using corrosion-resistant materials attached firmly to the drop pipe or pump column in such a manner as to prevent entrance of foreign materials.

3.2.6.7. Permanent observation wells

If they are to remain in service after completion of a water supply well, observation wells shall be constructed in accordance with the requirements for permanent wells and protected at the upper terminal to preclude entrance of foreign materials.

3.2.7. Liners.

Liners are not casings and are not a substitute for properly casing and grouting a well. Liners are generally used for three purposes. First is to hold the well bore open below the casing point when caving or spalling rock is encountered. These may be a combination of liner and screens to allow water flow from the lined portion of the bore hole. Second is to seal off portions of the bore hole below the casing point that are causing water quality issues. Third is to line the well casing to address casing damage, casing corrosion or iron bacteria growth on the casing.

3.2.7.1. General Specifications and guidelines

a. The approval of the department shall be obtained prior to the installation of any liner.
b. Steel liners shall be new and have an inside diameter no less than 4-inches and a minimum wall thickness no less than 0.188 inches.

c. Plastic liners shall have an inside diameter no less than 4-inches and meet American Society for Testing and Materials (ASTM) standards concerning thermoplastic well casing and be composed of polyvinyl (PVC) or acrylonitrile-butadiene-styrene (ABS) materials formulated for well casing.
d. Plastic liners shall have Standard Dimension Ratio (SDR) rating or no greater than 21 or a schedule rating no less than Schedule 80.
e. All liners used to seal out potential groundwater contamination areas below the existing casing or to correct inadequate grouting seals of the casing annulus, and other problems arising concerning the contamination of subsurface water shall have their upper end set at the top of the well casing. The liner shall be secured in the hole by an approved method.
f. Packers shall be secured on plastic liners with screws (making sure they do not penetrate the liner) or other methods and on steel liners the packer shall be welded or mechanically attached so that it will not move during liner placement.
g. Whenever a liner is needed it is recommended that the bottom of the liner be at the bottom of the well and that it be a combination of liners and screens. This will help prevent potential future problems with pump replacement.

3.2.7.2. Method of installation

a. When liners are used only to hold open the well bore they may be placed in the well following normal industry installation procedures and shall be secured in the hole by approved packers or if a steel liner by swaging.
b. When liners are used only to hold open the well bore and water flow is desired from the area to be lined, slotted liners shall not be used. Instead a combination of well screen and liners shall be used. Well screens shall meet the requirements of section 3.2.5.9.
c. All other liners must be sealed into place by the following procedures.
    1. The liner must have a rubber packer (first packer) secured near the bottom of the interval to be grouted. Another rubber packer (the second packer) must be secured about twenty feet (20') above the first packer. This will result in two (2) rubber packers spaced about twenty feet (20') apart on the liner. These packers must hold the grout in place. Grout must be placed between the first and second packer and completely fill this interval as the liner is being installed into the casing. Grout must also be placed on top of the second packer filling it to at least a point twenty feet (20') above the third packer. Care must be taken by the well installation contractor when selecting the type of grout used, keeping in mind the time of liner installation and grout set-up time. The liner shall be placed into the well casing being careful not to damage the packers or liner, or two (2) packers must be placed close together near the bottom of the liner and grouted after the liner is set by pressure grouting through a tremie pipe. The bottom sixty feet (60') of annulus created when installing a liner must be grouted. A minimum annulus of one half inch (1/2") must be present to grout a liner.

2. Alternate grouting procedures will be considered on a case-by-case basis. Written approval in advance by the division is required.

d. PVC and ABS liners shall not be used when known gasoline or solvent contamination exists within 300 feet of the well being repaired or drilled. When gasoline or solvent contamination levels do not present a potential threat to the integrity of the pipe or liner, the use of PVC or ABS pipe material will be considered on a case-by-case basis. Approval must be received in advance.

3.3 Project Completion

As required by 10 CSR 60-10.010, upon completion of the project, the engineer of record must submit two sets of as-built plans, or plans of record, for the project along with department form "Statement of Work Completed". Any modifications to the project not shown on the approved plans and specifications must be reflected in as-built drawings submitted to the department. For wells, the size, thickness, upper and lower elevations and method of sealing of all casings or liners installed in the well shall be shown on the plans and adequately explained in plan notes. Detailed specifications on any packers or liners used shall be provided.

Table 4 – Steel Pipe

STEEL PIPE					
SIZE (inches)	**DIAMETER (inches)**		**WALL THICKNESS (inches)**	**WEIGHT (pounds/feet)**	
	Outside	**Inside**		**plain ends (calculated)**	**threads & couplings (nominal)**
6 I.D.	6.625	6.065	0.280	18.97	19.18
8	8.625	7.981	0.322	28.55	29.35
10	10.750	10.020	0.365	40.48	41.85
12	12.750	12.000	0.375	49.56	51.15
14 O.D.	14.000	13.250	0.375	54.57	57.00
16	16.000	15.250	0.375	62.58	
18	18.000	17.250	0.375	70.59	
20	20.000	19.250	0.375	78.60	
22	22.000	21.000	0.500	114.81	
24	24.000	23.000	0.500	125.49	
26	26.000	25.000	0.500	136.17	
28	28.000	27.000	0.500	146.85	
30	30.000	29.000	0.500	157.53	
32	32.000	31.000	0.500	168.21	
34	34.000	33.000	0.500	178.89	
36	36.000	35.000	0.500	189.57	

Chapter 4 -- Treatment

4.0. General.

The design of treatment processes and devices shall depend on evaluation of the nature and quality of the particular water to be treated and the desired quality of the finished water.

4.1. Clarification.

Plants using conventional clarification to treat water prior to filtration shall be designed to:

a. Provide at least a two-stage treatment process consisting of primary rapid mixing, flocculation and sedimentation and secondary rapid mixing, flocculation, and sedimentation, in series, to treat surface water**;**
b. Provide at least single stage treatment consisting of rapid mix, flocculation and sedimentation for clarification to treat groundwater under the direct influence of surface water**;**
c. Permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time;
d. Have walls and interior equipment constructed of stainless steel or non-metallic materials or provide duplicate parallel units;
e. Avoid constructing conventional cylindrical settling units because of their excessive short-circuiting and poor flow characteristics;
f. Be started manually following shutdown, unless otherwise approved by the department where automatic monitoring control is provided;
g. Minimize hydraulic head losses between units to allow future changes in processes without the need for pumping;
h. Prevent raw water from being discharged directly into the filters; and
i. Provide a minimum of two clarification units in parallel for single stage treatment if the units or their major interior components are painted steel. As an alternative, the unit and all major interior equipment shall be made of stainless steel or materials with similar corrosion resistance.

4.1.1. Presedimentation, or raw water storage basins.

a. Presedimentation basin is recommended for water systems taking water from navigational rivers.
b. Storage Capacity. Presedimentation basins should be sized so that the river intake can be shut down to allow spill and/or contamination to pass before resuming normal operation**.**
c. Inlet. Incoming water shall be dispersed across the full width of the line of travel as quickly as possible; short-circuiting must be minimized.
d. Bypass. Provisions for bypassing presedimentation basins shall be included.

4.1.2. Rapid Mix

a. Rapid mix shall mean the rapid dispersion of chemicals throughout the water to be treated, by violent agitation. The engineer shall submit the design basis for the velocity gradient (G-value) selected, taking into consideration the chemicals to be added, water temperature, color, and other water related water quality parameters. Interference between treatment chemicals and the optimum locations and sequences for feeding different chemicals shall be considered in rapid mix design. Multiple rapid mix or chemical injection points may be necessary.
b. Equipment. Basins should be equipped with mechanical mixing devices**.** Static mixing may be considered if the treatment flow is not variable and can be justified by design engineer.
c. Mixing. The detention period shall not be more than 30 seconds at the maximum design flow rate.
d. Location. The rapid mix and flocculation basins shall be as close together as possible. The connecting piping between them shall be designed to prevent chemical buildup.

4.1.3. Flocculation.

Flocculation is a process to enhance the collection of smaller floc particles into larger, more easily settleable particles through gentle stirring by hydraulic or mechanical means**.**

a. Inlet and outlet design shall minimize short-circuiting and destruction of floc. Bottom outlets that allow flocculation basins to drain for maintenance into sedimentation basins must be valved or gated.
b. Detention. The detention time for floc formation shall be at least 30 minutes. The department may consider reduced detention time for ballasted flocculation or for tapered flocculation with diminishing velocity gradient if justified by the engineer. Series compartments or tapered flocculation are recommended to further minimize short-circuiting and to provide decreasing mixing energy with time. Basins shall be designed so that individual basins may be isolated without disrupting plant operation.
c. Provide a minimum of two flocculation units in parallel for single stage treatment if the units or their major interior components are painted steel. As an alternative, the unit and all major interior equipment shall be made of stainless steel or materials with similar corrosion resistance.
d. Flow velocity. The velocity of flow through the flocculation basin shall not be less than 0.5 feet per minute nor greater than 1.5 feet per minute.
e. Equipment. Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 3.0 feet per second. Turbine, radial flow type impellers should not be used for flocculation because of their high shear rates. When agitators with axial flow and hydrofoil impellers are used, the designing engineer shall specify the desired velocity gradient (G) range, impeller tip speed, ratio of impeller diameter to equivalent tank diameter and superficial velocity range. The impeller tip speed should not exceed 8 ft/sec for a three or four-blade hydrofoil. The superficial velocity should not be less than 3 ft/min nor

greater than 10 ft/min. The ratio of the impeller diameter to equivalent tank diameter should not be less than 0.30 nor larger than 0.45.

f. Piping. Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to settling basins shall be not less than 0.5 feet per second or greater than 1.5 feet per second. Allowances must be made to minimize turbulence at bends and changes in direction.

g. Other designs. Baffling may be used to provide for flocculation in small plants only after consultation with the department. The design should be such that the velocities and flows noted above will be maintained.

h. Superstructure. A building over the flocculation basins may be required.

i. Accessibility. Each flocculation basin shall permit observation and easy access

j. Safety. Permanent ladders or handholds should be provided on the inside walls of basins and shall comply with latest OSHA regulations. Guard rails should be provided for any floors or walkways adjacent to open basins.

k. Underwater light. To assist in determining presence of floc, effective size, and density, an underwater light should be installed in flocculation chambers approximately 12 inches below the normal water level of the basin.

4.1.4. Sedimentation.

Sedimentation, a process for removal of solids before filtration by gravity separation, shall follow flocculation. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units:

a. Conventional rectangular settling units shall have a minimum length to width ratio of three to one (3:1) or shall have baffles that will provide a flow path that gives the same ratio;

b. Detention Time. Settling units shall provide a minimum of four hours of settling time. This may be reduced to two hours for lime-soda softening facilities treating only groundwater. The volume that will be used in determining the detention time shall be calculated using the effective dimensions of the basin. The effective length is measured from the inside edge of the last influent weir or launder to the inside edge of the first effluent weir or launder. The effective side water depth is measured from the effluent level of the launders or submerged orifices to the bottom of the basin. The volume above the submerged orifices should not be included when calculating for the detention time. Where a mechanical residuals scraper is not provided and residual storage volume is allocated at the bottom of the basin, the effective side water depth shall be measured above the allocated residual storage. Reduced sedimentation time may be approved when equivalent effective settling is demonstrated;

c. Inlet Devices. Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin;

d. Outlet Devices. Outlet weirs or submerged orifices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow. Outlet weirs and submerged orifices shall be designed as follows:
   1. The rate of flow over the weirs shall not exceed 20,000 gallons per day per foot of the outlet launder;
   2. Submerged orifices shall be designed to provide an even flow across the launder to prevent excessive water velocities and to minimize headloss;
   3. Submerged orifice launders should not be located lower than three feet below the water surface; and
   4. The entrance velocity through the submerged orifices shall be sufficient to provide enough headloss that even flow is provided through each orifice, but shall not exceed 0.5 feet per second.

e. Depth of Basin. A minimum side water depth of ten feet must be provided. Where mechanical residuals removal is not provided, additional basin depth shall be required for residuals storage.

f. Velocity. The velocity through settling basins shall not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Fixed or adjustable baffles must be provided as necessary to achieve the maximum potential for clarification.

g. Overflow. An overflow weir or pipe designed to establish the maximum water level on top of the filters should be provided. The overflow shall discharge by gravity with a free fall at a location where the discharge will be noted.

h. Superstructure. A superstructure over the sedimentation basins may be required particularly for water systems that may have problems controlling disinfection byproducts. A cover may be provided in lieu of a superstructure if:
   1. Provisions are included for adequate monitoring under all weather conditions;
   2. There is no mechanical equipment in the basin; and
   3. The basin is equipped with mechanical residuals removal, large access ways shall be provided for maintenance. The access ways shall be sized and located to provide safe ventilation during basin maintenance and allow easy removal and replacement of the mechanical residuals removal equipment.

i. Residuals Collection. Mechanical residuals collection equipment should be provided.

j. Drainage. Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one foot in 12 feet where mechanical residuals collection equipment is not required.

k. Flushing Lines. Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the department.

l. Safety. Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guardrails should be included. Compliance with other applicable safety requirements, such as OSHA, should be considered.

m. Residuals Removal. Residuals removal design:

1. Shall have residuals pipes that are a minimum of three inches in diameter and arranged to facilitate cleaning;
2. Shall prevent clogging particularly at the entrance to residuals withdrawal piping;
3. Shall have valves located for ease of accessibility for operation and maintenance; and
4. Should include provisions for the operator to observe and sample residuals being withdrawn from the unit.

n. Residuals Management. Facilities for residuals handling and disposal shall be reviewed and approved by the Water Pollution Control Program of this department. The required NPDES (National Pollutants Discharge Elimination System) permit(s) must be obtained before constructing or operating the residuals facilities.

4.1.5. Solids Contact Unit.

Units are normally acceptable for combined softening and clarification where water characteristics are not rapidly variable, flow rates are uniform, and operation is continuous. Solids contact units do not work well treating low turbidity waters or waters where the characteristics vary widely or rapidly. Before considering solids contact as clarifiers without softening, specific approval of the department shall be obtained based on records of turbidity fluctuations, color, temperature, alkalinity, and hardness. Solids contact units may be considered only as primary clarifiers. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flows that are less than the design rate due to changes in water characteristics. Secondary stage treatment by conventional methods must be provided for surface waters. For a single stage treatment, a minimum of two solids contact units in parallel shall be provided or the unit and all its interior equipment shall be made of stainless steel or materials with similar corrosion resistance.

4.1.5.1. Installation.

Supervision by a representative of the manufacturer shall be provided with regard to all mechanical equipment at the time of installation and initial operation.

4.1.5.2. Operation.

Adequate piping with suitable sampling taps strategically located to permit the collection of water samples and residuals from critical portions of the units shall be provided. Sampling taps shall be provided at the residuals withdrawal level and preferably spaced at two-foot intervals from the basin bottom to two feet below the effluent level. The location of the sampling taps shall allow safe and easy access for routine sampling and be provided with facilities for easy cleanup. Before the units are placed in service, the following shall be provided for proper operation:

a. A comprehensive operating manual for the unit and its equipment including "as-built" detailed drawings of the unit, equipment and accessories;
b. Training of operating personnel;
c. A complete outfit of tools and accessories; and

d. Necessary laboratory equipment.

4.1.5.3. Chemical feed.

a. Chemicals shall be applied at such points and by such means as to ensure satisfactory mixing of the chemicals with the water. Interference between treatment chemicals and optimum locations and sequences for feeding different chemicals shall be considered. Multiple rapid-mixing facilities or chemical injection points may be necessary.

b. Cross-connection control must be provided for the make-up water lines of each chemical**.**

c. All chemicals shall meet AWWA Standards and must be certified for drinking water use under ANSI/NSF Standards 60/61.

4.1.5.4. Rapid mixing.

To ensure proper mixing of applied chemicals, a rapid mixing device or a chamber ahead of solids contact units shall be required for units treating surface water and may be required for units treating other waters. Mixing devices employed shall be constructed to:

a. Provide good mixing of the raw water with chemicals added; and

b. Prevent deposition of solids in the mixing zone.

4.1.5.5. Solids Contact Mixing.

Mixing equipment shall:

a. Be adjustable in speed and/or pitch over a range consistent with the type of raw water being treated and the residuals being developed;

b. Provide a solids circulation rate of 3 to 6 times the design rate of flow of the unit, based on a liquid flow volume;

c. Provide for coagulation in a separate chamber or baffled zone within the unit; and

d. Provide at least 30 minutes of flocculation and mixing time.

4.1.5.6. Residuals concentrators.

a. The equipment should provide either internal or external concentrators in order to obtain concentrated residuals with a minimum of waste water.

b. Large basins should have at least two sumps for collecting residuals with one sump located in the central flocculation zone.

4.1.5.7. Residuals removal.

The residuals removal design shall:

a. Have residuals pipes that are a minimum of three inches in diameter and arranged to facilitate cleaning;

b. Prevent clogging at the entrance to residuals withdrawal piping;

c. Provide permanent fittings to allow flushing or unplugging of the blow-off lines;

d. Have valves located outside the tank for accessibility, and housed to prevent freezing; and

e. Provide for automatic residuals removal. Timers on automatic valves shall be designed to allow frequency and duration intervals to be set to provide frequent operation for very short intervals. Design of automatic valves shall provide for fast opening and closing that will be compatible with the required short interval residuals removal, and should include provisions for the operator to observe and sample residuals being withdrawn from the unit. Residuals shall discharge into a facility that is approved and permitted by the Water Pollution Control Branch of this department.

4.1.5.8. Cross-connections.

a. Blow-off outlets and drains must terminate and discharge at places satisfactory to the department.
b. Cross-connection control must be included for the potable water lines used to backflush residuals lines.

4.1.5.9. Detention period.

The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Calculation of detention time for settling shall not include the volume of the flocculation or mixing zone or the volume of water above submerged launders or orifices. Based on design flow rates, the detention time shall be no less than:

a. Two and one-half to four hours for suspended solids contact softeners treating surface water;
b. One and one-half to two hours for the suspended solids contact softeners treating only ground water; and
c. Four hours for contact units used for clarification of surface water.

Higher rates may be considered based on satisfactory results of pilot or full-scale testing with documentation that shows the units will provide nationally recognized optimum turbidity removal at the higher rate.

4.1.5.10. Suspended slurry concentrate.

Softening units should be designed so that continuous slurry concentrates of one percent (1%) or more, by weight, can be satisfactorily maintained. In general, softening efficiency improves as suspended slurry concentration increases, although with very high slurry concentration, carry-over is a problem.

4.1.5.11. Water losses.

a. Units shall be provided with suitable controls for residuals withdrawal.
b. The total water losses should not exceed:
   1. Five percent for clarifiers; or
   2. Three percent for softening units.
c. Solids concentration of residuals bled to waste should be:
   1. Three percent by weight for clarifiers; or
   2. Five percent by weight for softeners.

4.1.5.12. Weirs or orifices.

a. The units shall be equipped with either overflow weirs or orifices constructed so that water does not travel more than ten feet horizontally to the collection trough or launder.

b. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank. However, peripheral weirs or launders shall not be used as they cause excessive short-circuiting.

c. Weir loading shall not exceed ten gallons per minute per foot of weir length.

d. Where orifices are used, the loading rates per foot of launder should be equivalent to weir loading rates and shall produce uniform rising rates over the entire area of the tank.

e. Weirs and orifices should be at least two feet from the tank wall to minimize carry-over.

4.1.5.13. Upflow rates.

a. The upflow rates shall be determined at the residuals separation line, approximately four feet below the collection weirs or orifices.

b. Unless supporting data is submitted to justify higher rates, the upflow rates shall not exceed:

   1. Seventy-five hundredths (0.75) gallon per minute per square foot for units used for clarifiers, or
   2. One (1.0) gallon per minute per square foot for units used for softening.

4.1.6. Tube or plate settlers.

A proposal for settler unit clarification must include pilot plant and/or full-scale demonstration data on water with similar quality prior to the preparation of final plans and specifications for approval. Settler units consisting of variously shaped tubes or plates may be installed in multiple layers at an angle to the flow in the sedimentation basin to enhance settling of solids. Raw water physical characteristics should be thoroughly tested for dissolved gasses and potential for off-gassing in considering the design of the unit, and the need for possible pretreatment prior to the settler unit(s).

4.1.6.1. General Criteria.

a. Inlet and outlet considerations – The design shall maintain velocities suitable for settling in the basin and minimize short-circuiting. Inlets to plate settlers shall be designed to evenly distribute the water across the units and to minimize cross flows and eddy currents within the plates. Outlet weirs or launders shall be constructed so that water above the settlers does not travel more than ten feet horizontally to the collection trough or launder. Outlet weir loading shall not exceed ten gallons per minute per foot of weir length. Where orifices are used, the loading rates per foot of launder should be equivalent to weir loading rates and shall produce uniform rising rates over the entire area above the settlers.

b. Settlers shall be installed in basins with a quiescent zone and a settler zone separated by baffles. The interface between the quiescent zone and the settler zone shall be designed to evenly direct the water to the settlers. Water velocities under the settlers should not be greater than 0.05 feet per second.

c. Drainage – Drain piping from the basin must be sized to facilitate a quick flush of the of the settler units and to prevent flooding of the portions of the plant. Basins should have hopper bottom and residuals removal equipment.

d. Protection from freezing – Outdoor installation must provide sufficient freeboard above the top of the settlers to prevent freezing in the units. A cover or enclosure is strongly recommended.

e. Application rate for tubes – A maximum rate of 2-GPM/square foot of cross-sectional area for tube settlers unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.

f. Application rate for plates – A maximum loading rate of 0.5 GPM/ square foot for plate settlers, based on 80 percent of the projected horizontal plate area.

g. The superstructure or support system for the settlers shall be made of stainless steel, aluminum or materials with similar corrosion resistance. The support system shall be able to carry the weight of the modules when the basin is drained plus any additional weight to support maintenance

h. Flushing lines – Air or water flushing lines shall be provided to facilitate maintenance and must be properly protected against backflow or back siphonage.

i. Provisions shall be made to allow the water level to be dropped for cleaning the modules. At least a 2-inch water supply line shall be provided near the settlers to support at least a one-inch hose and nozzle for manually cleaning the settlers and the basin. Sufficient walk ways around or across the settler area shall be provided to facilitate safe cleaning of the settlers. When the water supply line is finished water, appropriate backflow protection shall be provided.

4.1.7 High rate clarification processes

High rate clarification processes may be approved upon demonstrating satisfactory performance under on-site pilot plant conditions or documentation of full scale plant operation with similar raw water quality conditions as allowed by the reviewing authority. Reductions in detention times and/or increases in weir loading rates shall be justified. Examples of such processes may include dissolved air flotation, ballasted flocculation, contact flocculation/clarification, helical upflow, and solids contact units.

4.2. Filtration.

Filtration is a process for removing particulate matter from water by passing through porous media. Pretreatment shall be required prior to filtration unless otherwise approved by the department. Acceptable filters shall include the following types: rapid rate gravity filters, rapid rate pressure filters, and membrane filters. Other types of filters maybe considered if justified by the engineer through pilot or full-scale testing. The application of these types of filters must be supported by water quality data representing a reasonable period of time to characterize variations in water quality.

4.2.1. Rapid rate gravity filters.

4.2.1.1. Rate of filtration.

The design rate shall be a maximum of two gallons per minute per square foot of the filter surface area. Higher rates may be considered based on raw water quality, degree of pretreatment provided, type of filter media, water quality control parameters, competency of operating personnel, and other factors as required by the department. In any case, the filter rate must be proposed and justified by the designing engineer to the satisfaction of the department prior to the preparation of final plans and specifications.

4.2.1.2. Number.

At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with the largest filter removed from service. Provisions to control the flow into or from each filter and to divide flows equally between each active filter must be provided.

4.2.1.3. Structural details and hydraulics.

Where painted steel filters are provided, they should be individual stand alone filters with sufficient space provided around each filter to facilitate painting and maintenance. Manufactured multi-cell filter units should be avoided unless constructed of stainless steel or similar corrosion resistant material. Where manufactured multi-cell filter units are provided, each cell shall be capable of operating independently and of being drained and removed from service for maintenance while the other cells are in operation. Consideration shall be made to the expected life of the filter and the debt service of the treatment facility. The filter structure shall be designed to provide for:

a. Vertical walls within the filter;
b. No protrusion of the filter walls into the filter media;
c. No protrusion of pipes, structural supports, brackets or other devices into or through the filter media unless specifically approved by the department;
d. Cover by superstructure (roof drains must not discharge into the filters);
e. Head room to permit normal inspection, operation and safe access to the media for surface washing, manual cleaning and removal and replacement of the media, wash water troughs and underdrains;
f. Minimum depth of filter box of 8½ feet;
g. Minimum water depth over the surface of the filter media of three feet;
h. Trapped effluent to prevent backflow of air to the bottom of the filters;
i. Prevention of floor drainage to the filter with a minimum four-inch curb around the filters;
j. Prevention of flooding by providing overflow;

k. Maximum velocity of treated water in pipe and conduits to filters of two feet per second;

l. Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy, or following lime-soda softening;

m. Wash water drain capacity to carry maximum flow;

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n. Walkways around filters, to be not less than 24 inches wide;

o. Safety handrails or walls around all filter walkways;

p. Adequate lighting to clearly view the entire surface of each filter during filter washing with lights located so that bulbs can be safely changed from operating floor or filter walkways;

q. Filter piping and valves sufficient to allow each filter to operate independently, to be drained and removed from service for maintenance and to be surface washed, operated to waste, and backwashed while the other filters are in normal operation;

r. Auxiliary manual operators for essential filter valves when pneumatic or electric operated filter valves are provided. The default or off setting of all automated filter valves shall be in the closed position unless otherwise justified;

s. Filter piping that is not solvent welded or threaded plastic pipe of any type. Preferred pipe is painted ductile iron or steel pipe, mechanical joint or flanged with stainless steel bolts and nuts;

t. Adequate space, headroom and access to allow for removal and repair of each filter valve. For gate valves larger than six inches in diameter, consideration shall be given to access of mechanical equipment to lift and transport the valves;

u. Construction to prevent cross connections and common walls between potable and nonpotable water, including flumes and gullets; and

v. Filter to waste piping for filtering to waste each filter at normal filtration rates until the turbidity of the filter effluent drops to an acceptable level. Piping shall allow the other filters to operate normally while any filter is being operated to waste. An air gap or other backflow prevention assembly shall be provided in the waste line. A throttling valve or valves shall be provided in the filter-to-waste piping to assure that the designed rate of flow of each filter is not exceeded when filtering to waste. Controls for filtering to waste should be incorporated with the other filter controls.

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4.2.1.4. Wash water troughs.

Wash water troughs shall be designed to have:

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a. The bottom of the troughs above the maximum level of expanded media during washing;

b. The troughs carry the maximum rate of wash water with a two-inch freeboard;

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c. The top edge of the troughs level and all at the same elevation;

d. The troughs spaced so that each trough serves the same number of square feet of filter area; and

e. The maximum horizontal travel of suspended particles to reach the trough not to exceed three feet.

4.2.1.5. Filter material.

a. All filter materials shall meet the current AWWA standards for filtering materials. The media shall be clean silica sand or other natural or synthetic media approved by the department, having the following characteristics:
   1. A total depth of not less than 24 inches and generally not more than 30 inches;
   2. A minimum of 12 inches of media having an effective size range no greater than 0.45 mm to 0.55 mm, and specific gravity greater than other filtering materials within the filter; and
   3. A uniformity coefficient of the smallest material not greater than 1.65.

b. Types of filter media.
   1. Anthracite - Clean crushed anthracite, or a combination of anthracite and other media may be considered on the basis of experimental data specific to the project, and shall have:
      a. Effective size of 0.45 mm - 0.55 mm with uniformity coefficient not greater than 1.65 when used alone,
      b. Effective size of 0.6 mm – 0.8 mm with a uniformity coefficient not greater than 1.85 when used as a cap; and
      c. As an exception, effective size for anthracite used alone on potable groundwater for iron and manganese removal only shall be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon onsite pilot plant studies).
   2. Sand. Filter sand shall have an effective size of 0.45 mm to 0.55 mm and a uniformity coefficient of not greater than 1.65.
   3. Granular Activated Carbon (GAC) – Granular activated carbon as a single media may be considered for filtration only after pilot or full-scale testing. The design shall include the following:
      a. The media must meet the basic specifications for filter media in this section. Larger size may be allowed where pilot or full-scale tests have demonstrated that treatment goals can be met under all conditions;
      b. There must be provisions for a chlorine residual and adequate contact time in the water following filters and prior to distribution;
      c. There must be means for periodic treatment of filter material for control of bacterial and other growth; and
      d. Provisions must be made for frequent replacement or regeneration.
   4. Other filter media – Other media will be considered based on experimental data and operating experience.

c. Torpedo sand - A three-inch layer of torpedo sand shall be used as a supporting media. When underdrains using strainers, nozzles, or other distributors are used, the torpedo sand shall extend at least 3 inches above the top of the distributors. The torpedo sand shall have:

1. Effective size of 0.8 mm to 2.0 mm; and
2. Uniformity coefficient not greater than 1.7.

d. Gravel.

1. Gravel, when used as the supporting media shall be cleaned and washed hard, durable, rounded silica particles and shall not include flat or elongated particles. The minimum thickness of each gravel layer shall not be less than twice the size of the biggest possible particle. The coarsest gravel shall be 2 1/2 inches in size when the gravel rests directly on a lateral system, and must extend above the top of the perforated laterals. A minimum of four layers of gravel shall be provided in accordance with the following size and depth distribution:

Size	**Depth**
2 1/2 to 1 1/2 inches	5 to 8 inches
1 1/2 to 3/4 inches	3 to 5 inches
3/4 to 1/2 inches	3 to 5 inches
1/2 to 3/16 inches	2 to 3 inches
3/16 to 3/32 inches	2 to 3 inches

2. Reduction of gravel depths, number of layers and size gradations may be considered upon justification to the department by showing conformance to AWWA standards when proprietary filter bottoms are specified. However, all filters shall have a minimum of a three-inch layer of torpedo sand used as a supporting media for filter media which shall meet the above requirements.

4.2.1.6. Filter bottoms and strainer systems.

Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms shall not be used where iron or manganese or hardness precipitation may clog them or with waters softened by lime. The manifold-type collection systems shall be designed to:

a. Minimize loss of head in the manifold and laterals;
b. Ensure an even distribution of wash water and an even rate of filtration over the entire area of the filter,
c. Provide the ratio for the area of the final openings of the strainer systems to the area of the filter at about 0.003,
d. Provide the total cross-sectional area of the laterals at about twice the total area of the final openings,
e. Provide the cross-sectional area of the manifold at 1½ to 2 times the total area of the laterals;
f. Provide spacing of the laterals not to exceed 12 inches; and
g. Provide spacing of the perforations along the lateral not to exceed eight inches.

4.2.1.7. Surface wash and subsurface wash.

Air scouring with backwash is the preferred method for washing a filter.

1. *Air scouring*

Air scouring shall be based on the following standards:

a. Air scouring controls must allow the operator to control the air and water flow rates and duration. Rate of flow indicators for air and water shall be provided. Provide manual over-ride to the automated backwash controls for backwashing the filters including air scour. Automated backwash controls shall not automatically start filter backwash. Filter backwashing must be initiated manually;

b. Air flow for air scouring the filter must be three to five cubic feet per minute per square foot of filter area when the air is introduced in the underdrain; a lower air rate may be used when the air scour distribution system is placed above the underdrains;

c. Air scouring shall be followed by a fluidization wash to restratify the media;

d. Air must be free from contamination;

e. Air scour distribution system should be placed at or below the media and supporting bed interface; if placed at the interface, the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system;

f. Piping for the air distribution system shall not be flexible hose which may collapse when not under pressure and shall not be relatively soft material which may erode at the orifice opening with the passage of air at high velocity;

g. Air delivery piping shall not pass down through the filter media unless a minimum of two anti-seepage collars, six inches apart are provided around each pipe. The anti-seepage collars shall extend three inches out from the pipe and be continuous around the entire circumference of the pipe. No arrangement in the filter design shall allow short circuiting between the applied unfiltered water and the filtered water;

h. Consideration should be given to maintenance and replacement of air delivery piping;

i. The backwash water delivery system must be capable of 15 gallons per minute per square foot of filter surface area; however, when air scour is provided, the backwash water rate must be variable and should not exceed 8 gallons per minutes per square foot unless operating experience shows that a higher rate is necessary to remove scoured particles from filter media surfaces;

j. The filter underdrain shall be designed to accommodate air scour piping when the piping is installed in the underdrain;

k. The water fluidization wash part of the air scour facilities shall meet all of the requirements of subparagraph 4.2.1.7 section 4; and

l. Duplication of air compressors or blowers shall be provided unless manual surface wash facilities meeting the requirements of subparagraph 4.2.1.7 are provided.

2. Surface Wash

Surface wash must be followed by backwash. Surface wash facilities are required except for pressure filters or where air scour is used.

a. Surface wash facilities must include:

1. A 1 ½ - inch to 2- inch pressure line located conveniently on the filter plant operating floor and equipped with suitable lengths of 1-inch to 1 ½ - inch pressure hose and nozzle; and
2. A suitable rack should be available for storing the hose.

3. Auxiliary surface or subsurface wash

Auxiliary surface or subsurface wash may be accomplished by a system of fixed nozzles or a revolving type apparatus. All devices shall be designed with:

a. Provisions for water pressures of at least 45 psi;
b. A properly installed backflow prevention assembly to prevent back siphonage if connected to the treated water system; and
c. Rate of flow of 2.0 gallons per minute per square foot of filter area with fixed nozzles or 0.5 gallons per minute per square foot with revolving arms.

4. Backwash

Provisions shall be made for washing filters as follows:

a. A minimum backwashing rate of 15 gallons per minute per square foot, consistent with water temperatures and specific gravity of the filter media shall be provided. A rate of 20 gallons per minute per square foot or a rate necessary to provide for a 50 percent expansion of the filter bed is recommended. A reduced rate of 10 gallons per minute per square foot may be acceptable for full depth anthracite or granular activated carbon filter media;
b. Filtered water provided at the required rate by wash water tanks, a wash water pump, from the high service main, or a combination of these;
c. Wash water pumps in duplicate unless an alternate means of obtaining wash water is available and if air scouring is provided, duplicate air compressors/blowers except where water flow is adequate to backwash the filters at the required rates with water alone;
d. Not less than 15 minutes wash of one filter at the design rate of wash;
e. Timer to record total backwash time;
f. A wash water regulator or valve on the main wash water line to obtain the desired rate of filter wash with the wash water valves on the individual filters open wide;
g. A totaling rate of flow on the main wash water line, with an indicator so that it can be easily read by the operator during the washing process; and

h. Equipment designed to prevent rapid changes in backwash water flow.

4.2.1.8. *Appurtenances.*

a. The following shall be provided for every filter:
   1. Influent and effluent sampling points;
   2. An indicating, and preferably recording, loss of head gauge or transmitter;
   3. An indicating rate of flow meter. A rate controller that limits the rate of filtration to a maximum rate through each filter may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a control valve or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the department;
   4. Influent or effluent controls that distribute plant flows evenly between the filters and limit the flow rate of each filter to the maximum approved rate;
   5. Provisions for filtering to waste, with appropriate measures for backflow prevention; and
   6. A continuous turbidity monitoring and recording meter on the effluent of each filter connected so that it monitors the filter effluent both when the filter is operating normally and to waste. Digital readouts for each filter shall be provided in main operating area of the filters where they can be easily viewed by the operators when operating the filters. Data collection facilities for the monitors shall allow the data to be displayed graphically.

b. It is recommended the following be provided for every filter:
   1. Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing;
   2. A minimum 1½ inch pressure hose equipped with shut-off nozzles or valve and storage rack at the operating floor for washing filter walls;
   3. Particle monitoring equipment as a means to enhance treatment operation when treating surface waters;
   4. A throttling valve or flow rate controller capable of providing gradual rate increases when placing the filters back into operation; and
   5. Automated shutoff valves on each filter effluent to prevent the filters from draining down after the plant is shut off;

c. The filter basins must be provided with overflow piping.

4.2.2. Rapid rate pressure filters.

4.2.2.1. *General.*

a. The normal use of these filters is for iron and manganese removal. Pressure filters shall not be used in the filtration of surface water or groundwater under the direct influence of surface water or following a lime-soda softening process**.**

b. The minimum requirements regarding number, rate of filtration, structural details and hydraulics, filter media, etc., for rapid rate gravity filters (subsection 4.2.1.) also applies to pressure filters, where appropriate.

4.2.2.2. Rate of filtration.

The rate of filtration shall not exceed three gallons per minute per square foot of the filter area. Higher rates may be considered based on satisfactory results of pilot or full-scale testing. The filter piping must be arranged as simple as possible to provide for filtration, backwashing and filtering to waste of each filter individually. For horizontal filters, the design filter area shall be based on only that area that has 24 inches or more of filter media above the support gravel, underdrain or filter walls and with at least 12 inches of media having an effective size range no greater than 0.45 mm to 0.55 mm.

4.2.2.3. Details of design.

The filters shall be designed to provide for:

a. Loss of head gauges on the inlet and outlet pipes of each filter;

b. A climate controlled building with adequate heating, ventilation and humidity control to house the filters, piping, other equipment and appurtenances;

c. Filter piping and valves sufficient to allow each filter to operate independently and to be drained and removed from service for maintenance while the other filters are in normal operation;

d. Filter piping that is not solvent welded or threaded plastic pipe of any type. Preferred pipe is painted ductile iron or steel pipe, mechanical joint or flanged with stainless steel bolts and nuts

e. An easily readable meter or flow indicator on each battery of filters and throttling valves on each filter to manually control the rate of low. Automatic rate of flow controllers are preferred on each filter. A flow indicator is recommended for each filtering unit where the filter influent or effluent automatically distributes the flow evenly between active filters;

f. Sufficient space and headroom around each filter to allow for routine painting of the filters their piping and appurtenances;

g. Vertical pressure filters are preferred. For horizontal filters, the approved design filter area shall be only that area that has 24 inches or more of filter media above the support gravel, underdrain or filter walls, with at least 12 inches of media having an effective size range no greater than 0.45 mm to 0.55 mm, and a specific gravity greater than other filtering materials within the filter;

h. Minimum side wall shell height of six feet. A corresponding reduction in sidewall height is acceptable where proprietary bottoms permit reduction of the gravel depth;

i. The top of the wash water collectors to be at least 18 inches above the surface of the media;

j. The underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 20 gallons per minute per square foot of filter area;
k. Backwash flow indicators and controls that are easily readable while operating the control valves for filter effluent piping that exits the filter below the top of the underdrain. Filter effluent piping shall not extend above the underdrain inside the filter;
l. An air release valve on the highest point of each filter;
m. At least a 24-inch diameter access way to facilitate inspection, repairs and removal of filter media for each filter 36 inches or more in diameter. Sufficiently sized access ways shall be provided for filters less than 36 inches in diameter**;**
n. Means to observe the wastewater during backwashing; and
o. Construction to prevent cross-connection.

4.3. Membrane Filtration Design.

Four categories of membrane filtration are generally recognized. They are microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. One can find a number of definitions for these categories but for the purposes of this design standard they are set strictly by membrane pore or theoretical particle removal size and are as follows:

Microfiltration covers a pore size range of 0.1 to 2.0 microns;
Ultrafiltration covers a pore size range of 0.01 to 0.1 microns;
Nanofiltration covers a theoretical particle removal size range of 0.001 to 0.01 microns; and
Reverse Osmosis covers a theoretical particle removal size range of 0.0001 to 0.001 microns.

Using these definitions means that microfiltration does not remove microbiological contaminants and that only nanofiltration and reverse osmosis provide virus removal.

4.3.1. Membrane materials.

Two types of membranes are typically used for reverse osmosis and nanofiltration. These are cellulose acetate based and polyamide composites. Membrane configurations typically include tubular, spiral wound and hollow fiber. Microfiltration (MF) and nanofiltration (NF) membranes are most commonly made from organic polymers such as: cellulose acetate, polysulfones, polyamides, polypropylene, polycarbonates, and polyvinylidene. The physical configurations include: hollow fiber, spiral wound, and tubular. Operational conditions and useful life vary depending on type of membrane selected, quality of feed water, and process operating parameters. Some membrane materials are incompatible with certain oxidants. If the system must rely on pre-treatment oxidants for other purposes, for example, zebra mussel control, taste and odor control, or iron and manganese oxidation, the selection of the membrane material becomes a significant design consideration.

4.3.2. Membrane filtration performance.

Membrane filtration performance is highly site specific. Therefore, pilot studies shall be done to assure that an acceptable quality finished water will be produced through all the source water seasonal quality variations. Pilot plant studies will be required to determine the best membrane to use, the need for pretreatment, type of post treatment, the bypass ratio, the amount of reject water, system recovery, process efficiency, particulate and organism removal efficiencies, cold and warm water flux, fouling potential, operating and transmembrane pressure and other design and monitoring considerations. The selection of membrane treatment shall be determined by source water quality characteristics, treated water quality requirements, the targeted materials to be removed, membrane pore size, molecular weight cutoff, membrane materials and system treatment configuration. All membranes must be certified by the National Sanitation Foundation International (NSF) to contain no leachable surfactants or other chemicals. Membrane replacement represents a major component in the overall cost of water production. Life expectancy of a particular membrane under consideration shall be evaluated during the pilot study or from other relevant available data. Membrane life may also be reduced by operating at consistently high fluxes. Membrane replacement frequency is a significant factor in operation and maintenance cost comparisons in the selection of the process. Power consumption may be a significant cost factor for reverse osmosis plants. The power consumptions of a particular membrane under consideration shall be evaluated during the pilot study or from other relevant data.

4.3.2.1. Removal of microbiological contaminants.

When membrane filtration is proposed for removal of microbial contaminants, the membrane used must be certified by NSF to remove the contaminants expected. Membrane filtration does not produce a residual that can be monitored to determine inactivation credit for the removal of microbiological pathogens. For most systems it is not feasible to do routine tests for viruses or virus indicators, cryptosporidium or giardia. Therefore, one must rely on direct and indirect integrity testing to decide if safe water is being produced. The federal regulatory framework requires that challenge testing, direct integrity testing and indirect continuous integrity monitoring comply with pathogen specific criteria. This criterion requires that direct integrity tests and indirect continuous integrity monitoring must have a resolution in the same size range as the pathogen to be removed. Currently, direct integrity test methods (pressure or vacuum decay, diffusive air flow test, water displacement test) are adequate for cryptosporidium and giardia sized particles but do not feasibly detect virus-sized breaches in membranes. It is possible that a number of very small integrity breaches could allow the passage of viruses through the membrane barrier undetected, contaminating the permeate. The indirect continuous integrity testing currently available (turbidity monitors, particle counters) are adequate for cryptosporidium and giardia sized particles but do not detect virus sized particles. Consequently, membrane filtration is not accepted as a method to meet virus inactivation and removal requirements. Therefore membrane filtration shall be followed by disinfection with at least the required detention time for virus removal.

4.3.2.2. Removal of inorganic compounds.

In order to meet lead and copper action levels and to prevent sorption of other regulated contaminants, the finished water produced shall be noncorrosive. Both nanofiltration and reverse osmosis remove inorganic compounds with the species and amount dependent on the molecular weight cutoff of the membrane. To produce a noncorrosive water, either chemicals must be fed to or feed water blended with, the permeate (filtrate). Any feed water blended shall meet all required microbiological maximum contaminant levels and treatment technique requirements for the source water. The finished water shall meet all primary and secondary maximum contaminant levels.

4.3.3. Pretreatment determination.

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Pretreatment is normally required for all types of membrane filtration, to assure removal of color, tastes and odors, to control membrane fouling and to assure useful membrane lives. The type of pretreatment required depends on the characteristics of the source water and the type of membrane filtration selected. For reverse osmosis and nanofiltration processes, pretreatment is usually needed for turbidity reduction, iron or manganese removal, stabilization of the water to prevent scale formation, microbial control, chlorine removal (for certain membrane types), and pH adjustment.

4.3.3.1. Source water testing.

Extensive testing of the source water for all parameters to identify conditions that may affect membrane filtration and finished water quality shall be done. Tests shall include, but not be limited to iron, manganese, color, dissolved gases, water temperature, turbidity, total dissolved solids, hardness, alkalinity and pH.

4.3.3.2. Seasonal source water variation.

Since the source water quality may vary seasonally, sampling shall cover at least one full year.

4.3.3.3. Water quality extremes.

Historic information shall be reviewed to determine water quality extremes that may be expected.

4.3.3.4. Test results.

Tabulated results of tests done and summaries and conclusions shall be submitted as a part of the engineering report proposing membrane filtration.

4.3.3.5. Chemical compatibility.

The compatibility of the membrane material with the chemicals fed during pretreatment shall be considered.

4.3.4. Design Flux.

Design flux is the volume of water that can move through a given area of membrane in a given time, usually measured in gallons per square foot per day (GFD). The type of membrane material, the characteristics of the raw water, operating pressures, degree of pretreatment, the style of membrane, etc., determine design flux. Information on each of these parameters shall be provided in submittals to the department. Most membranes have a much higher theoretical capacity than possible to realize in actual long term stable operation. It is common to down rate the design flux determines by pilot studies by 25% or more. The flux used to design a specific installation depends on the purpose of the installation and the degree of system integrity required. The greater the number of membrane fibers required to produce a given output of water the smaller the impact of bypass flow from a single break. Thus, for removal of microbial contaminants, lower than average design fluxes should be used. Justification for the design flux used shall be provided in the submittal to the department. Design considerations and membrane selection must address the issue of target removal efficiencies and system recovery versus acceptable trans-membrane pressure differentials.

Deleted: Reverse osmosis design should provide for a flux of at least 15 . Microfiltration design fluxes average around 70 . Nanofiltration and ultrafiltration design fluxes fall proportionally in-between.

4.3.5. Design Pressure Drop or Transmembrane Pressure.

Design pressure drop or transmembrane pressure is the pressure differential range required across the membrane to produce at the design flux for a normal filter run. Large pressure differentials require high influent pressures, increase operating costs, and shorten membrane life. Also, bypass flow from membrane fiber breakage is proportional to the pressure differential across the membrane. Pretreatment and membrane selection shall be done to provide the lowest practical design pressure drop.

4.3.6. Membrane Fouling.

Fouling and scaling characteristics of the source water and design cleaning frequency shall be considered. Design shall include provisions for minimizing membrane fouling.

4.3.6.1. System integrity.

System integrity and reliability shall be considered in the design. Multiple membrane arrays, skids or trains shall be provided. The treatment system shall be able to meet maximum design flows while the largest capacity membrane array, skid or train is out of service for membrane replacement, testing, back washing or cleaning.

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4.3.6.2. Membrane design.

Design shall include piping, valves, fittings and other provisions for isolation and easy removal of membrane arrays, skids or trains and of individual membrane modules for replacement, testing, backwashing and cleaning.

4.3.6.3. Operational testing.

Design shall provide for equipment and laboratory facilities to perform daily routine testing of the raw and finished water and at selected locations in the pretreatment process to control the treatment processes and water quality.

4.3.6.4. Direct testing equipment.

Equipment for direct testing shall be provided to monitor membrane integrity and to detect and locate defects or breaches that could allow feed water to bypass membrane filtration. Direct testing equipment shall include but not be limited to equipment for bubble testing and conducting pressure or vacuum hold testing of membrane modules. Any air compressors used shall not impart oil into the compressed air. Furthermore, air filtration shall be provided to assure that the membranes are not contaminated with airborne pathogens.

4.3.6.5. Indirect continuous integrity testing.

Indirect continuous integrity testing currently consisting of at least turbidity monitors and particle counters shall be provided. Methods for recording and presenting the results graphically shall be provided. Membranes used to treat surface water shall have automatic shut down controls if indirect continuous integrity tests exceed pathogen specific set points.

4.3.6.6. Membrane backwashing and air filtration.

Provisions for backwashing microfiltration and ultrafiltration membranes shall be provided using reverse flow of water and/or pressurized air. Since backwashing is frequent, duplication of equipment is necessary to assure continuous plant operation. If pressure air is used, the air compressors shall not impart oil into the compressed air. Furthermore, air filtration shall be provided to assure that the membranes are not contaminated with airborne pathogens.

4.3.6.7. Chemical cleaning.

Detailed information on the proposed membrane manufacturer's cleaning requirements and types of cleaning chemicals shall be submitted as a part of the application for approval. The method of cleaning and chemicals used must be approved by the department. Provisions for safely storing, handling, feeding and disposing of these chemicals and the resulting waste shall be part of the design. Cross connection control considerations must be incorporated into the system design, particularly with regard to chemical feeds and waste piping used for membrane cleaning, waste stream and concentrate.

Deleted: Equipment and appurtenances necessary for chemical cleaning of the membranes shall be provided.

4.3.7. Membrane Rating.

When rated by pore size, membranes have been classified as either nominal or absolute. Nominally rated membranes are rated at the size on their particle retention curve where the membrane retains 98% of those sized particles. Absolute rated membranes have a maximum pore size of the rated size and retain 100% of particles that are the same size as the pore size rating of the membrane. Although the concept of using the nominal or absolute pore size is sometimes used in reference to the filtration capabilities of membrane material, this concept is overly simplistic and does not fully characterize the removal efficiency of a membrane. Federal rules and policy require that membrane filtration performance be determined by challenge testing in which the ability of the membrane module to reject the organism (or a suitable surrogate) or size particle is demonstrated. The challenge testing shall be done by a reputable third party organization such as the National Sanitation Foundation or the Underwriters Laboratory. Molecular cut-off weight is sometimes used to rate membranes used for nanofiltration and reverse osmosis.

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Deleted: Specifications shall clearly state whether membrane pore size is nominal or absolute. Nominal size membranes shall be followed by additional treatment.

4.3.8. Recovery.

Recovery is the amount of finished treated water produced, including water needed for backwashing and other maintenance purposes, from a given amount of feed water. Pilot tests shall be done to determine the rate of recovery for each facility. Design of the membrane treatment facility as to size, number of units, redundancy, finished water storage and pumping requirements and so forth shall be based on the average recovery or rate of permeate production at the coldest probable water temperature. Since water temperature can have a significant impact on flux, it is common practice to "normalize" the flux to a reference temperature of 20 degrees Celsius during operation for the purpose of monitoring system productivity independent of changes in water temperature.

Deleted: Design percent recovery should be more than 80%.

4.3.9. Membrane Filtration Design.

The following shall be addressed in membrane filtration design:

a. A climate controlled building with adequate heating, ventilation and humidity control to house the filters, piping, appurtenances, pumps, laboratory and other equipment;

b. Redundancy of membrane arrays, skids or trains shall be provided sufficient to meet maximum design flow at the highest expected design pressure drops and lowest expected temperatures of the water to be treated with the largest capacity array, skid or train out of service. Redundancy of critical control components including, but not limited to, valves, air supply, and computers shall be provided. If two-stage membrane treatment is provided, redundancy shall be provided in each treatment stage. Redundancy shall be provided for pretreatment and post treatment facilities necessary for the effective operation of the membrane treatment and of the control of finished water quality. Redundancy shall be provided for feed water, filtrate, backwash, recirculation and other necessary pumps serving multiple membrane skids or arrays;

c. If automatic starting, stopping and washing of membrane treatment is proposed, array and backwash pumps shall either be variable speed or equipped with soft start and stop capabilities or slow opening and closing automated valves shall be provided to prevent damage to the membranes or their containers;

d. The design shall provide for plugging off and replacing failed membrane fibers, tubes or modules. The necessary equipment, valves, piping and appurtenances shall be provided to easily shut off individual membrane modules and to locate, remove, and replace defective fibers, tubes, or modules;

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e. The design shall provide for pressure gauges on the influent and effluent piping to each membrane array, skid or train. Preferably these pressures should be measured by pressure transducers with digital read outs and continuous recorders. At a minimum, the gauges shall be 4½-inch diameter, liquid filled, sealed gauges correct to within ½ of 1% of full scale;

f. Meters shall be provided to determine the rate of flow and amount of raw water and finished water pumped. On each membrane skid or array, meters shall be provided to determine the rate-of-flow and amount of feed water, concentrate, filtrate or permeate and backwash water pumped.

g. Online particle sizing and counting equipment shall be provided on the effluent piping of each membrane array, skid or train that will measure in the 2 to 5 micron range. Turbidity monitoring equipment shall be provided for on the influent and effluent piping of the membrane arrays, skids or trains. Continuous recording equipment shall be provided for turbidity and for the particle counters. This equipment shall connect with an alarm system to warn operators of excessive particle or turbidity breakthrough. Alternative testing devices may be considered on a case-by-case basis depending on water quality and purpose of the treatment; and

Deleted: in the 2 to 5 micron range.

h. Design life of the membranes should be greater than four years.

4.3.10. Flow Meters.

Totaling rate of flow meters shall be provided on the source water influent piping, the plant finished water piping, on membrane backwash piping, on plant water use piping and on cross-circulation or retentate piping.

4.3.11. Post Treatment.

Post treatment shall be provided for neutralization of aggressive water, disinfection with the required contact time, and maintenance of distribution system disinfectant residuals.

4.3.12. Waste Disposal.

The ability to properly dispose of the wastes generated by membrane filtration is an important factor in the location and design of a facility. Provision shall be made for disposing of retentate, backwash water, chemical cleaning and other wastes generated by membrane filtration for compliance with requirements in 10 CSR 20.

4.3.13. Special considerations for bag and cartridge filtration.

Bag and cartridge filtration systems are based on the physical screening process to remove particles. This technology is designed to treat low turbidity (less than 3 NTU) raw water and to meet the low flow (less than 50 GPM) needs of small systems. Bag and cartridge filtration does not remove tastes, odors, color, organic chemicals and most inorganic chemicals. Additional treatment must be provided to treat water containing these contaminants or any other contaminant that cannot be removed purely by filtration. In a bag filtration unit, water is treated by passing through a bag-shaped filter where the particulates are collected allowing filtered water to pass to the outside of the bag. Cartridge filters are woven or pleated cylinders that fit in a housing that directs water through the filter material. Both bag and cartridge filters are manufactured and supplied by a variety of companies and are available in a variety of material compositions and pore size ratings (typically from 1 to 40 micron). The particulate loading capacity of these filters is low, and once expended the bag or cartridge filter must be discarded.

4.3.13.1. Removal of microbial contaminants.

Filter performance shall be determined by challenge testing in which the ability of the filter to reject the organism, size particle or a suitable surrogate is demonstrated. The bag and cartridge filters must fit the housing, and different manufacturer's products may not be interchangeable. Challenge testing shall be done on filter unit meaning both the filter and the housing manufactured for the filter. The challenge testing shall be done by a reputable third party organization such as the National Sanitation Foundation or the Underwriters Laboratory. The demonstration of filtration is specific to a specific housing and a specific bag or cartridge filter. Any other combinations of different bags, cartridges, or housings will require additional demonstration of filter efficiency. If operated in series the final filter shall have an absolute maximum pore size smaller that the size of the organism being removed. Neither bag nor cartridge filters remove viruses. Therefore, for systems treating surface water, groundwater under the direct influence of surface water or groundwater required to meet 4-log inactivation and removal of viruses, bag and cartridge filters must be followed by continuous disinfection with at least the detention time necessary to provide 4-log inactivation of viruses.

4.3.13.2. Removal of inorganic compounds.

Bag and cartridge filtration has been used to remove low (< 1.0 mg/l) levels of iron. Dissolved or ferrous iron is not removed by bag or cartridge filtration. Before iron can be removed it must be converted from a ferrous to a ferric state by oxidation. Oxidation is generally done by chlorinating the water prior to filtration. Sufficient time must be provided after adding chlorine to allow the oxidation reaction to occur prior to the filters. Bag and cartridge filtration has been used to remove low levels of turbidity (less than 3 NTU) not associated with surface water. Pretreatment may be required for water with turbidity that exceeds 3 NTU. Frequently when removing iron or turbidity bag or cartridge filters are operated in series with larger pore size filters as the first stage. Justification for the pore sizes proposed for each filter stage shall be provided.

4.3.13.3. Bag and Cartridge filter performance.

Filter performance depends upon the degree of filtration and filter life. The finished water must meet all applicable primary and secondary maximum contaminant levels for the type of water treated while maintaining an economically feasible filter replacement rate. Pilot tests should be done, and may be required by the department to determine the effective life of all bags or cartridges proposed to be used and replacement costs estimated for one year of operation. The number of bag or cartridge modules required and the optimum flow rate through each module must be determined. The maximum allowable pressure differential across each bag or cartridge filter module must be determined.

4.3.13.4. Treatment testing.

Design shall provide for equipment and laboratory facilities to perform daily routine testing of the raw and finished water and at selected locations in the treatment process to control the treatment processes and water quality. For systems treating surface water or groundwater under the direct influence of surface water, testing equipment shall be provided that will perform pH, temperature, free and total chlorine residual, turbidity, total alkalinity and total hardness tests. For systems treating groundwater for iron removal, testing equipment shall be provided to perform tests for ferrous and total iron and free and total chlorine residuals. Additional tests may be required depending upon the quality of the raw water and the purpose of the treatment.

4.3.13.5. Indirect continuous integrity testing.

For systems treating surface water or groundwater under the direct influence of surface water, indirect continuous integrity testing consisting of at least continuous turbidity monitoring and recording shall be provided on the effluent of each final filter stage. Methods for recording and presenting the results graphically shall be provided. Bag and cartridge filters used to treat surface water or groundwater under the direct influence of surface water shall have automatic shut down controls if indirect continuous integrity tests exceed pathogen specific set points.

4.3.13.6. Bag and Cartridge Filtration Design.

The following shall be addressed in bag and cartridge filtration design:

a. A climate controlled building with adequate heating, ventilation and humidity control to house the filters, piping, appurtenances, pumps, laboratory and other equipment.
b. Piping, valves and fittings to allow for the isolation and removal of filter modules and pretreatment facilities.
c. Easy access to filter modules for replacement of filters.
d. Floor drains to handle spillage when changing filters;

e. A minimum of two bag or cartridge filter treatment trains shall be provided for water systems that must provide water continuously or that cannot discontinue water service to replace filters.
f. System components such as housing, cartridges, bags, gaskets and O-rings shall be certified for performance with ANSI/NSF Standard 61. The materials in contact with the water shall not impart undesirable taste, odor, color or materials to the water as a result of the presence of constituents in materials of construction. Additional testing may be required by the department.
g. The flow rate through the treatment process and each filter train shall be metered and be equipped with a valve to control flow. The flow rate through each bag or cartridge filter must not exceed the maximum flow rate verified by filtration efficiency testing.
h. Pretreatment is strongly recommended to provide a more consistent water quality to the bag and cartridge filters and to extend bag and cartridge life. Examples of pretreatment include media filters and larger pore size bag or cartridge filters.
i. For systems treating surface water or groundwater under the direct influence of surface water or groundwater required to provide virus inactivation or removal, chlorine or another disinfectant shall be added prior to the filters to control the growth of algae, bacteria, etc., on the filters. The impact on disinfection-by-product formation should be considered.
j. A sampling tap shall be provided ahead of any treatment so a source water sample can be collected. Sampling taps shall be provided before and after each bag or cartridge filter module.
k. Pressure gages shall be installed before and after pretreatment and before and after each bag or cartridge filter module.
l. An automatic air release valve shall be installed on top of each filter housing.
m. Frequent start and stop operation of the bag or cartridge filter shall be avoided to minimize filter breakthrough. To avoid this frequent start and stop cycle the following options are recommended:
    1. A slow opening and closing valve ahead of the filter to reduce flow surges.
    2. Reduction of the flow through bag or cartridge filters to as low as possible to lengthen filter run times.
    3. Installation of a circulating pump that pumps treated water back to a point ahead of the bag or cartridge filter. Care must be taken to make sure there is no cross connection between the finished water and raw water.
    4. Sizing the capacity and controlling the operation of finished water storage facilities to minimize start and stop cycling.
n. A pressure relief valve or similar mechanism shall be incorporated into the bag or cartridge filter housing to allow the cartridges or bags to be removed or replaced.

o. Complete automation of the treatment system is not required. Automation of the treatment plant should be incorporated into the ability of the water system to monitor the finished water quality. It is important that a qualified water operator trained in using this equipment is available to run the treatment plant.
p. Facilities to disinfect the housing and to run water to waste each time the cartridge or bag filter vessels are opened for maintenance. Design must insure that no untreated or under treated water bypasses a cartridge. The potential exists for bypassing around the end seals of some cartridges and voids have been found in the sealing O-rings of certain cartridges. Manufacturer or preferably third party certification shall be provided that leakage does not occur at the proposed filter operating pressures. A design proposing the stacking of cartridges in a single housing shall not be approved because of the increased probability of leakage.
q. Facilities shall be provided to run water to waste so that a minimum of two housing volumes is discharged to waste cycle following an interruption in flow;
r. All multiple cartridge filter housings shall be certified against deflection during pressurization that could result in unseating of cartridge elements end seals. Stainless steel housings are preferred.
s. All filter housings shall be designed to withstand a hydrostatic pressure of at least 125 psi.

4.4. Disinfection.

4.4.1. Regulatory Considerations.

Requirements for disinfection and disinfection residuals are found in 10 CSR 60-4.055 Disinfection Requirements and 10 CSR 60-4.025 Ground Water Rule. 10 CSR 60-4.055 also provides the department the authority to require any public water system to disinfect and to provide the detention time deemed necessary by the department. Disinfection by-products are regulated pursuant to 10 CSR 60-4.090 Maximum Contaminant Levels and Monitoring Requirements for Disinfection By-Products. 10 CSR 60-4.052 requires systems treating surface water or groundwater under the direct influence of surface water to notify the department before making any changes to the point of disinfection, disinfectants used, disinfection process, or any other significant disinfection alteration and submit to the department at least the following:

a. A completed disinfection profile and disinfection benchmark for Giardia lamblia and viruses as described in section (9) of the rule;
b. A description of the proposed change in disinfection practice; and
c. An analysis of how the proposed change will affect the current level of disinfection.

4.4.2. Use of Disinfectants

Continuous disinfection is recommended for all primary water supplies.

a. Free chlorine using break point chlorination is the preferred method of disinfection.

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b. Disinfection may be accomplished with liquid chlorine, calcium or sodium hypochlorite, chlorine dioxide, or ozone.

c. Other chemical disinfecting agents will be considered, provided reliable application equipment is available and testing procedures for a residual are recognized in the latest edition of "Standard Methods for the Examination of Water and Wastewater."

d. Disinfection is required at all surface water supplies, ground water sources under the direct influence of surface water, and at any ground water supply of questionable sanitary quality or where treatment is provided that could potentially result in the water becoming microbiologically contaminated.

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e. Disinfection with chloramines is not recommended for primary disinfection to meet the CT requirements for systems treating surface water, ground water under the influence of surface water, or groundwater required to provide 4-log removal or inactivation of viruses.

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f. In a conventional filtration treatment plant, softening plant, and iron and manganese removal plant, provisions should be made for applying disinfectant to the influent of each sedimentation basin, filter influent, and water entering the clearwell, and water entering the distribution system.

Deleted: Chlorine dioxide shall not be used as distribution system disinfection.

g. Systems using chloramines as the disinfectant residual entering the distribution system must add and mix the chlorine prior to the addition of ammonia.

h. When a chemical disinfectant is fed for taste and odor control, color removal or for purposes other than disinfection, the design shall meet all of the requirements necessary for feeding that chemical as a disinfectant. Sufficient contact time must be provided to assure that the intended reactions are complete and the desired water quality is achieved. Analysis equipment must be provided sufficient to control the treatment process and water quality.

4.4.3. Contact time and point of application.

a. Due consideration shall be given to the contact time of the disinfectant in water with relation to pH, ammonia, taste-producing substances, temperature, bacterial quality, disinfection by-products formation potential and other pertinent factors. Disinfectant shall be applied at a point that will provide adequate contact time. All required disinfectant contact time should be provided after filtration. All basins, tanks, containers and other facilities used for disinfection contact time shall be designed to minimize short-circuiting. Specific consideration shall be given to influent and effluent arrangements, water level controls and internal baffling.

b. For surface water systems and ground water systems under the direct influence of surface water:

   1. The disinfectant contact time must be determined by Tracer Studies as explained in Appendix B of the "Guidance Manual for Surface Water System Treatment Requirements." The tracer study is required for a new treatment plant prior to receiving final approval from the department for permission to operate;

2. The disinfection treatment must provide a sufficient CT (Disinfectant residual concentration multiplied by the contact time) value to ensure that the total treatment process achieves the required inactivation and/or removal of *Giardia lamblia* cysts Cryptosporidium, and viruses. The percentage of *Giardia lamblia* cyst, Cryptosporidium and virus removal by the disinfection process shall be determined by calculating the CT value and comparing the calculated CT value with the corresponding water characteristics on the CT tables in Appendix C of the Guidance Manual for Surface Water System Treatment Requirements;
3. If the system uses a primary disinfectant other than chlorine, the system must demonstrate to the department that the treatment process can satisfactorily inactivate and/or provide the required log removal of *Giardia lamblia* cysts and viruses depending on the type of source water used.

c. For groundwater systems required to provide 4-log inactivation and/or removal of viruses, the disinfection treatment must provide a sufficient CT value to ensure that the total treatment process achieves the required inactivation and /or removal of viruses by comparing it to the values in the Missouri Guidance Manual for Inactivation of Viruses in Groundwater; and

d. For groundwater systems that add a chemical disinfectant, but are not required to provide 4-log virus inactivation and/or removal, disinfection facilities shall be designed to provide the residuals required in Section 4.4.2 Residual Disinfectant of this guide.

4.4.4. Residual disinfectant.

a. Only free available chlorine or chloramines shall be used as the residual disinfectant in water entering the distribution system. The design shall provide for applying chlorine or chloramines prior to the filters with a residual maintained through the filters, except for granular activated carbon filters or contactors, to the water entering the distribution system, and at distant points in the water distribution system.

b. When chlorine is added to water containing naturally occurring ammonia, organo-chloramines are formed that are not disinfectants. When chloramines are used as the disinfectant, breakpoint chlorination must be provided in the treatment process before adding an approved ammonia compound to convert the chlorine to chloramines.

c. Disinfection facilities shall be designed to meet disinfectant demands and provide a minimum disinfectant residual in the water entering the distribution system of at least 1.0 milligrams per liter of free available chlorine or 2.0 milligrams per liter chloramines.

d. Disinfection facilities shall be adequately sized to meet disinfectant demands and provide a minimum free residual at distant points in a water distribution system of 0.5 milligrams per liter or 1.0 milligrams per liter chloramines. The equipment shall be of such design that it will operate accurately over the desired feeding range.

4.4.5. Testing equipment.

a. When chlorine dioxide is fed, equipment shall be provided for testing chlorine dioxide residuals and chlorite concentrations recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater.

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b. When ozone is fed, equipment shall be provided for testing ozone residuals recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater.

c. When chloramines is fed, equipment shall be provided for testing monochloramine residuals and free available ammonia concentrations recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater.

d. Chlorine residual test equipment shall meet the requirements established in 10 CSR 60-5.010 and shall be capable of measuring residuals to the nearest 0.2 milligram per liter. Laboratory grade or hand held colorimeters or spectrophotometers shall be available for all facilities feeding chlorine.

e. All treatment facilities treating surface water, groundwater under the direct influence of surface water or ground water requiring 4-log inactivation removal of viruses and serving a population greater than 3,300 shall be equipped with continuous recording chlorine analyzers monitoring water entering the distribution system.

   1. Continuous chlorine analyzers shall be connected into an alarm system that will directly notify a water operator of low or high chlorine residuals and that will automatically shut down the treatment facility if residuals drop below those necessary to adequately disinfect the water.
   2. Continuous chlorine analyzers should be provided to monitor chlorine residuals entering disinfection contact units and be connected into an alarm system that will directly notify a water operator of low or high chlorine residuals.
   3. All treatment facilities required to meet specific CT requirements shall have equipment for testing pH and temperature meeting the requirements established in 10 CSR 60-5.010.

4.4.6. Ultraviolet Disinfection

Ultraviolet (UV) light produced by UV lamps has been shown to be effective at inactivating protozoa (*Cryptosporidium* and *Giardia*) and bacteria (*Escherichia coli* and *Staphylococcus aureus*). It is less effective at inactivating certain types of viruses (adenovirus). UV light can be used as a disinfectant to meet the requirements of the SWTR (and all subsequent surface water treatment rules IESWTR, LT1SWTR, and LT2SWTR) and the Groundwater Rule (GWR). Drinking water applications generally use Low Pressure (LP), Low Pressure High Output (LPHO), or Medium Pressure (MP) mercury vapor lamps. UV disinfection cannot be used alone. Additional disinfection will be required for inactivation of target pathogens, as required by the department. Systems using ultraviolet light must feed either free available chlorine or chloramines as a distribution disinfectant and maintain the minimum disinfectant residuals entering and within the distribution system required in 10 CSR 60-4.055(3) and (4).

To receive treatment credit for UV light, systems must treat at least 95 percent of the water delivered to the public during each month by UV reactors operating within validated conditions for the required UV dose.

The ultraviolet light dose depends on the ultraviolet light intensity (measured by ultraviolet light sensors), the flow rate, and the ultraviolet light transmittance measured by laboratory equipment. A relationship between the required ultraviolet light dose and these parameters must be established and then monitored at the treatment plant to ensure sufficient disinfection of microbial pathogens. Validation testing using diodosimetry as prescribed by the United States Environmental Protection Agency must be conducted on the proposed ultraviolet disinfection equipment and calibrated to the specific water and conditions to be treated. Since the written approval of the department must be obtained prior to any installation of any ultraviolet light disinfection facilities, it is the responsibility of the system that chooses to use ultraviolet light to determine this relationship, provide the validation and calibration, provide information on the disinfection equipment and provide the continuous monitoring and recording equipment to ensure that adequate disinfection will occur before the department will approve installation.

Table 5 – UV Dose Requirements

Millijoules per centimeter squared (mJ/cm^2)

Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

4.4.6.1. Validation

a. UV water treatment devices must be validated by a third-party entity in accordance with the USEPA Ultraviolet Light Disinfection Guidance Manual (USEPA UVDGM). The validation must demonstrate that the unit is capable of providing the necessary UV light dose in units of millijoules per square centimeter (mJ/cm^2) that will achieve the log removal for specific target pathogens.

b. Installed and replaced components should be equal to or better than the components used during validation testing.

Table 6 – Summary of Validation Requirements

Requirement	**Conditions**
Validated operating conditions must include	• Flow rate • UV intensity as measured by a UV sensor • UV lamp status
Validation testing must include	• Full-scale testing of a reactor that conforms uniformly to the UV reactors used by the water system

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	• Inactivation of a test microorganism whose dose response characteristics have been quantified with a low-pressure mercury vapor lamp
Validation testing must account for	• UV absorbance of the water • Lamp fouling and aging • Measurement uncertainty of on-line sensors • UV dose distributions arising from the velocity profiles through the reactor • Failure of UV lamps or other critical components • Inlet and outlet piping or channel configurations of the UV reactor

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4.4.6.2. System Design Criteria for UV Treatment Devices

a. Pre-Treatment

The water supply shall be analyzed for the following water quality parameters and the results shall be included in the UV application. Pretreatment is required for UV installations if the water quality exceeds any of the following maximum limits. When an initial sample exceeds a maximum limit, a check sample shall be taken and analyzed.

Raw water quality shall be evaluated and pretreatment equipment shall be designed to handle water quality changes. Variable turbidity caused by rainfall events is of special concern.

Table 7 – Water Quality Testing Parameters for UV disinfection

Parameter	Maximum
UV 254 nm Absorption	0.155 cm-l
Dissolved Iron	0.3 mg/L
Dissolved Manganese	0.05 mg/L
Hardness	120 mg/L
Hydrogen Sulfide (if odor is present)	Non-detectable
Iron Bacteria	None
pH	6.5 – 9.5
Suspended Solids	10 mg/L
Turbidity	1.0 NTU
Total Coliform	1,000 per 100 mL

b. System Design

The intensity and thus the disinfection effectiveness of ultraviolet lights decline as the lamps age. Furthermore, hard water found in most Missouri wells deposits hardness scale onto ultraviolet lamp sleeves, which decreases the lamp intensity and effectiveness. The scale also forms on the photo cell sensors, and affects their ability to measure disinfection effectiveness. Consequently, a system must prove to the department that it will have the equipment and trained staff necessary to properly operate, clean and maintain the UV light disinfection facilities before those facilities may be installed.

Any ultraviolet light disinfection installation must include strategically located photo cells that continuously monitor ultraviolet light intensity at 254 nanometers whenever the facility is operating. The monitors must be connected to an alarm system that includes a telephone dial system that notifies the operator when light intensities fail to meet required set points. The alarm system must include a critical function that automatically shuts off the water flow and shuts down the facility when light intensities fail to meet the critical set-point.

1. Plans and specification shall include the maximum and minimum flow rates, required UV dose, validation criteria, UV sensors, UVT analyzers, hydraulics, safeguards, and instrumentation and control.
2. A minimum of two UV treatment systems shall be installed in parallel. Each system shall be capable of treating the maximum design flow to assure continuous disinfection of the water supply when one unit is out of service, unless other satisfactory disinfection can be provided when the unit is out of service.
3. Air binding can interfere with the UV disinfection process or cause the lamps to overheat. The UV facility design should include a means for automatically releasing air prior to the UV reactor.
4. To address the increased potential for debris, UV facility designs for unfiltered applications should incorporate features that prevent potentially damaging objects from entering the UV reactor. The optimal approach is site-specific. Such features could include screens, baffles, or low-velocity collection areas.
5. UV reactors shall be placed after filtration if filtration is provided.
6. No bypasses shall be installed.
7. To avoid jetting flow, the inlet piping should have no expansions for at least ten (10) pipe diameters upstream of the reactor.
8. A flow meter and modulating control valve shall be installed for each UV reactor.
9. Each UV reactor should be capable of being isolated and removed from service. If the isolation valves are also used for flow control, the flow control valve shall be located sufficiently upstream or downstream of the UV reactor to limit the disturbance of the flow entering the UV reactor. Valve seats and other in-pipe seals and fittings within the straight pipe lengths adjacent to the UV reactors

should be constructed of materials that are resistant to UV light and chemicals that may be used for reactor cleaning. Automated flow control valves cannot be used as isolation valves.

10. The well or booster pump(s) shall have adequate pressure capability to maintain minimum water system pressure after the water treatment devices.

4.4.6.3 UV Assembly Design Criteria

a. The UV assemblies shall be accessible for visual observation, cleaning and replacement of the lamp, lamp jackets and sensor window/lens.
b. The UV housing shall be stainless steel 304 or 316L.
c. The proposed equipment should be able to withstand the maximum expected operating pressure, which may occur during a failure event.
d. To limit or prevent operator exposure to the UV light, UV reactors shall have interlocks that deactivate the lamps when reactors are accessed. Viewing ports, if provided, shall be fitted with UV filtering windows. A UV resistant face shield shall be provided for the operators when working in the UV reactor. To minimize the danger of exposure, warning signs also should be posted. All safety and operational precautions required by the National Electric Code (NEC), OSHA, local electric codes, and the UV manufacturer should be followed.
e. Design should ensure the UV lamps are submerged during operation, or automatically turned off when not submerged, to prevent overheating and UV equipment damage.
f. UV reactor manufacturers have developed different approaches for cleaning lamp sleeves, depending on the application. These approaches can include off-line chemical cleaning (OCC), on-line mechanical cleaning (OMC), and on-line mechanical-chemical cleaning (OMCC) methods. The reactor is filled with the cleaning solution for a time sufficient to dissolve the substances fouling the sleeves (minimum 15 minutes), rinsed, and returned to operation. The frequency of OCC can range from monthly to yearly and depends on the site-specific water quality and degree and frequency of fouling. OMC and OMCC systems use wipers that are attached to electric motors or pneumatic piston drives. MP equipment typically uses OMC or OMCC systems because the higher lamp temperatures can accelerate fouling under certain water qualities. The cleaning frequency for these OMC and OMCC systems typically ranges from 1 – 12 cycles per hour.
    1. All chemicals used for sleeve cleaning must be consistent with National Sanitation Foundation International/American National Standards Institute (NSF/ANSI) 60 Standard (Drinking Water Treatment Chemicals – Health Effects).

2. Methods for disposing of spent cleaning chemicals and waste must meet the requirements of the Missouri Clean Water Law and Regulations.

g. A wiper assembly or chemical cleaning-in-place system may be installed to allow in-situ cleaning of lamp jackets.

h. Adequate controls shall be in place to prevent contamination of the potable water with cleaning chemicals.

4.4.6.4. Start-up and operation considerations

a. Spare parts shall be provided for the UV lamps, sleeves, o-ring seals, and UV sensors. Spare parts should be provided for wipers, wiper drive mechanisms, ballasts, ballast cooling fans, reference UV sensors, and on-line UVT analyzers.

b. An automatic shutdown valve shall be installed in the water supply line ahead of the UV treatment system that will be activated whenever the water treatment system loses power or is tripped by a monitoring device when the dosage is below the validated operating design dose. When power is not being supplied to the UV unit the valve shall be in a closed (fail-safe) position.

c. A flow or time delay mechanism wired in series with the well or service pump shall be provided to permit a sufficient time for lamp warm-up per manufacturer recommendations before water flows from the unit upon startup. Where there are extended no-flow periods and fixtures are located a short distance downstream of the UV unit, consideration should be given to UV unit shutdown between operating cycles to prevent heat build-up in the water due to the UV lamp.

d. Supervision by a representative of the manufacturer shall be provided with regard to all mechanical equipment at the time of installation and initial operation.

e. No less than two(2) copies of manufacturer's recommended operation and maintenance procedures shall be furnished to the water system.

4.4.7. Other Disinfecting Agents.

Although disinfecting agents other than chlorine are available, each has demonstrated shortcomings when applied to a public water supply. Proposals for use of disinfecting agents other than chlorine, including ozone, chlorine dioxide and ultraviolet light, must be approved by the department prior to preparation of plans and specifications. Some disinfectants may be suitable as primary disinfectants but do not provide a residual or cannot be used as the disinfectant residual in the distribution system. Proposed designs for these facilities shall include provisions for monitoring and controlling chemical residuals that should not or cannot be used as the disinfectant residual in the distribution system.

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4.4.8. Ozone Disinfectant.

4.4.8.1. Bench scale studies.

Prior to the use of ozone for primary disinfectant, bench scale studies must be conducted for ground water sources and full scale pilot studies must be conducted for surface water and ground water under the influence of surface water sources. Tests shall be done to determine the production of bromates.

4.4.8.2. Chief operators.

Chief operators for water systems treating water with ozone must have the appropriate operator certification level required by the operator certification rules in 10 CSR 60-14.

4.4.8.3. Disinfectant residual.

Systems utilizing ozone for the primary disinfectant must provide for maintaining a residual of chlorine or chloramines in the distribution system.

4.4.9. Disinfection Byproduct and Precursor Removal and Control

Disinfection byproducts are formed when disinfectants react with naturally occurring organic substances. These organic substances, called "precursors," are a complex and variable mixture of compounds. Formation of disinfection byproducts is dependent on such factors as amount and type of disinfectant used, temperature, concentration and type of precursor, pH, and contact time. Pilot or full-scale studies for disinfection byproduct and precursor removal and control shall be performed. Any full plant trial studies or alterations to an existing treatment process shall be pre-approved by the department. 10 CSR 60-4.090 Maximum Contaminant Levels and Monitoring Requirements for Disinfection By-Products requires that before a community water system makes any significant modifications to its existing treatment process for the purposes of achieving compliance with the rule, the system must obtain department approval of its proposed modifications and those safeguards that it will implement to ensure that the microbiological quality of the drinking water served by the system will not be adversely affected by the modifications. At a minimum, the department shall require the system modifying its disinfection practice to evaluate the source water for microbiological quality, evaluate its existing treatment practices and consider improvements that will minimize disinfectant demand and optimize finished water quality throughout the distribution system, and conduct additional monitoring and studies as required by the department to assure continue maintenance of optimal biological quality in finished water. Water treatment plants for which construction is begun after the effective date of this document shall be designed with clearwells and other plant finished water storage sized to provide all of the required disinfectant contact time, CT, after filtration. These storage facilities must be baffled or otherwise designed to assure optimum detention and calculations submitted to support the basis of the design.

4.4.9.1. Methods of controlling precursors at the source.

a. Selective withdrawal from reservoirs. Varying depths may contain lower concentrations of precursors at different times of the year. Analyses for chlorophyll A and B may be useful in selecting withdrawal locations and in controlling plankton.

b. Plankton Control. Algae and their by-products act as disinfection byproduct precursors.
   1. Only algaecides approved by the department for use in potable water may be used for algae control in drinking water sources. Equipment for routine sampling and microscopic examination of the source water

shall be available to assure that over-treatment does not occur. The minimum equipment must include a microscope with built-in illumination, a Sedgwick-Rafter counting cell, and algae identification manuals.

2. Destratification of a water supply reservoir to reduce nutrients and thus plankton growth shall be supported by studies done on similar lakes that have been destratified. Furthermore, consideration shall be given to handling increased plankton growth during the first years of the operation. Watershed conditions that result in continuous high nutrient flow to a reservoir may negate any benefits in disinfection byproduct formation provided by destratification.
3. Alternative sources of better quality water should be considered, where available.
4. Development and implementation of watershed management plans to limit the amount of nutrients entering lakes and to reduce sediment buildup in lakes.

4.4.9.2. Removal of disinfection byproduct precursors and control of disinfection byproduct formation.

Design submittals for new plants or treatment changes on existing water sources shall include results of source water tests that cover at least a full calendar year to assure that the proposed treatment facilities will handle all source water conditions. Source water tests shall include bromides, total alkalinity, pH, turbidity, total organic carbon analyses and formation potentials for both trihalomethanes and haloacetic acids. Pilot or full-scale studies for disinfection byproduct and precursor removal and control shall be performed for methods proposed that use new or uncommon chemicals or processes. The following are some commonly used methods.

Deleted: . In addition, source water tests that cover at least a full calendar year are necessary to assure that the treatment facilities will handle all source water conditions.

a. Moving the point of chlorination to minimize disinfection byproduct formation.
b. Housing or covering treatment basins to reduce chlorine demands, moderate water temperature changes and control algae.
c. Control of chlorine doses and management of chlorine residuals to minimize disinfection byproduct formation.
d. Changing from free chlorine to chloramines as the distribution system disinfectant.
e. Adding oxidizing agents such as potassium permanganate, sodium permanganate, ozone, or chlorine dioxide to reduce the chlorine demand and thus the disinfection byproduct formation. Possible health effects of the byproducts produced by the oxidizing agents and the safety, storage, handling and feeding of these chemicals must be addressed in submittals to the department.
f. Adsorption by powdered activated carbon (PAC.) Studies using a variety of powdered carbons should be done to find the dosages required, the best application points and the most effective and least costly carbons. Provisions should be made for adding and mixing the carbon solution

before any coagulants are added and for providing a minimum 20 minute contact time with the water. Powdered activated carbon feeders shall be capable of feeding a dose of 50 mg/l at the designed capacity of the treatment plant.

g. Removal of precursors prior to chlorination by practicing enhanced coagulation or softening as explained by 10 CSR 60-4.090 Maximum Contaminant Levels and Monitoring Requirements for Disinfection By-Products, and by optimizing treatment processes Enhanced Coagulation and Softening are the primary methods required by regulation to meet total organic carbon reduction requirements for surface water. Plants that do no meet precursor removal requirements using other methods may be required to practice enhanced coagulation or softening. Because enhanced coagulation and softening produce large volumes of waste residuals, optimum methods for handling and disposal of waste residuals shall be considered in the design.

h. Systems treating surface water or ground water under the direct influence of surface water shall provide conventional water treatment. For surface water, conventional treatment is two stages of treatment provided as: primary rapid mix, flocculation and sedimentation followed by secondary rapid mix, flocculation and sedimentation, operated in series and followed by filtration and disinfection contact storage. For ground water under the direct influence of surface water, conventional treatment is defined as one stage of treatment consisting of secondary rapid mix, flocculation and sedimentation and followed by filtration and disinfection contact storage.

i. For existing treatment plants exceeding disinfection by-product maximum contaminant levels or not meeting total organic carbon removal requirements, a complete engineering study of all of the treatment processes shall be done to assure they are operating at their optimum. This study shall include a review of influent and effluent facilities for each treatment basin, evidence of basin short-circuiting, basin sizes and geometry, mixer design and chemicals fed and their efficiency. Modifying existing processes to assure optimum performance shall be considered.

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j. For proposed treatment plants, provide flexibility in chemical application and mixing to optimize treatment and avoid conflicts between treatment processes. Continuous monitoring and recording equipment shall be provided where appropriate.

k. Lowering the pH to inhibit the reaction rate of chlorine with precursor materials and to improve coagulation and removal of the precursors. Pilot or full plant trials should be done to determine the chemical processes required to stabilize the water. Noncorrosive finished water is required to meet secondary maximum contaminant levels and to assure compliance with the lead and copper rules in 10 CSR 60-15. Written approval of the department shall be obtained before conducting any full plant trials or changing the treatment process.

Deleted: 2. Adding oxidizing agents such as potassium permanganate, ozone, or chlorine dioxide to reduce the chlorine demand and thus the disinfection byproduct formation. Possible health effects of the byproducts produced by the oxidizing agents must be taken into consideration.¶
3. Adsorption by powdered activated carbon (PAC). Studies using a variety of powdered carbons should be done to find the dosages required, the best application points and the most effective and least costly carbons. Provisions should be made for adding and mixing the carbon solution before any other treatment chemicals are added and for providing a minimum 20 minute contact time with the water.¶

l. Induced draft aeration of the raw water with a high air to water ratio. Some believe that raw water aeration removes volatile organic precursors, oxidizes iron and manganese, and other compounds to reduce chlorine demands and increases water pH by removing carbon dioxide in the water.

m. Using various combinations of treatment to remove disinfection by-product precursors. Combinations of treatment are generally necessary to successfully meet disinfection byproduct standards.

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4.4.9.3. Removal of disinfection byproducts.

a. Aeration - by air stripping towers. Air stripping has been shown to remove trihalomethanes, but it has not proven successful for removal of haloacetic acids.

b. Adsorption by:

1. Granular activated carbon (GAC).

a. Methods shall be provided for monitoring carbon bed performance to determine when the carbon is exhausted for disinfection byproduct removal. Design should provide for carbon regeneration frequencies of no less than two years.

b. Methods shall be provided for monitoring the carbon beds to assure that microbiological growth in the carbon will not pass into the drinking water.

c. Carbon contactor design shall allow for backwashing or cleaning of the carbon bed to control microbiological growth and remove carbon fines. Surface wash facilities should be considered on down flow contactors.

d. Facilities for feeding a disinfectant and for providing disinfection contact time shall be provided following granular activated carbon filters or adsorption facilities.

e. For down flow contactors, the underdrains and support sand and gravel system shall be designed to capture carbon fines. Upflow contactors shall be followed by treatment facilities to remove carbon fines.

Deleted: Carbon shall be chosen to minimize carbon grain breakdown or methods provided to prevent carbon fines from passing into the drinking water.

f. Consideration shall be given to methods and ease of carbon removal and replacement.

g. Design shall provide for empty bed contact times of no less than 10 minutes at the design capacity of the treatment facilities using only that volume of the contactors containing granular carbon.

h. Pilot studies shall be done prior to preparation of plans and specifications to develop breakthrough curves; to determine usage rates; to determine the optimum carbon; to determine the optimum grain size of the carbon; and to determine if a 10 minute contact time is adequate.

i. At least two carbon contactors shall be provided in parallel and shall be designed to allow a contactor to be removed from service without affecting the operation of the remaining contactors.

j. Specific case-by-case approval shall be obtained by the department to use granular activated carbon adsorption facilities as filters and carbon contactors prior to the development of plans and specifications. Filters used as both filters and carbon contactors shall not have granular activated carbon as the only filter media. Filters used as both filters and carbon contactors shall meet all of the requirements for filters stated in Section 4.2 of this guide.

2. Synthetic Resins.
   a. Any resin proposed shall have NSF certification for use with potable water concerning leaching of chemicals into water.
   b. Methods shall be provided for monitoring resin bed performance to determine when the resin is exhausted for disinfection byproduct removal.
   c. Methods shall be provided for monitoring and controlling microbiological growth in the resin.
   d. Resin shall be chosen to minimize breakdown or methods provided to prevent resin fines from passing into the drinking water.
   e. Consideration shall be given to ease of resin removal and replacement.

4.4.9.4. Use of alternative disinfectants.

Disinfectants that react less with disinfection byproduct precursors may be used as long as pathogen control is maintained and disinfection byproduct and precursor removal standards are met. When using alternative disinfectants, facilities shall be provided to maintain required free chlorine or chloramines residuals in the water entering and in the distribution system. Possible health effects of the byproducts produced by alternative disinfectants must be taken into consideration. Written approval of the department shall be obtained before changing disinfectants. The alternative disinfectants listed below may be used.

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a. Chlorine Dioxide. Chlorine dioxide shall not be used as a distribution system disinfectant.

b. Chloramines. Chloramines are generally not suitable as primary disinfectants but may be used to provide required distribution system residuals. The following shall be considered before using chloramines.
   1. Existing facilities wanting to install chloramines disinfection shall do a disinfectant profile through the treatment plant and develop an inactivation benchmark. The results of the profile shall be submitted to the department along with the written request to change disinfectants.
   2. Nitrites and nitrates are primary health contaminants and must be kept below the maximum contaminant levels. Therefore, sampling in the distribution system shall be done to find if nitrification is occurring.
   3. Heterotrophic bacteria studies should be done routinely to assure that biological growths are controlled throughout the distribution system. Any study should include sufficient sampling to identify all problem areas.

4. To help control microbial growths, break point chlorination shall be obtained before adding ammonia to the water and converting to chloramines.
5. Chlorination facilities must be provided that will allow free chlorine residuals to be maintained throughout the distribution system.
6. All systems must notify all of its customers before converting to chloramines. Special care must be taken notify dialysis clinics, doctors clinics, hospitals, nursing homes, and home dialysis patients.

c. Ozone. Analyses for bromate production should be done early in the design process. Biological mediation or other byproduct removal processes shall be included as a part of the ozone facility design.

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4.5. Softening.

The softening process selected must be based upon the mineral quality of the raw water and the desired finished water quality in conjunction with requirements for disposal of residuals or brine waste, cost of plant, cost of chemicals and plant location. Applicability of the process chosen shall, be demonstrated.

4.5.1. Lime or lime-soda process.

Design standards for rapid mix, flocculation, and sedimentation are in subsection 4.2. Additional consideration must be given to the following process elements:

a. Hydraulics. When split treatment is used, the bypass line should be sized to carry total plant flow, and an accurate means of measuring and splitting the flow must be provided;

b. Aeration. Determinations should be made for the carbon dioxide content of the raw water. When concentrations exceed 10 milligrams per liter, the economics of removal by aeration as opposed to removal with lime should be considered if it has been determined that dissolved oxygen in the finished water will not cause corrosion problems in the distribution system. When split treatment is utilized, the split should be prior to aeration, and the re-blending prior to filtration;

c. Chemical feed point. Lime should be fed directly into the rapid mix basin;

d. Coagulants shall be selected that function in the high pH water encountered during lime softening. Aluminum sulfate (alum) in any of its forms does not function adequately at pH above 8.0.

e. Where slaking of quick lime is proposed, the designed capacity of the treatment facilities shall be considered. Manufactured lime slakers are sized for systems with designed flows of 1,000 gallons per minute or greater. Hydrated lime feeders should be provided for systems with a designed treatment capacity smaller than 1,000 gallons per minute.

f. Iron and manganese removal is not always incidental to lime softening. When the raw water contains concentrations of iron or combined concentrations of iron and manganese of 20 mg/l or greater or contains organic bound iron or manganese, additional treatment processes may be needed to assure adequate removal of the iron or manganese.

g. Rapid mix. Rapid mix basins must provide 30 seconds detention time with adequate velocity gradients to keep the lime particles dispersed;

h. Stabilization. Equipment for stabilization of water softened by the lime or lime-soda process is required;

i. Residuals collection and disposal.

    1. Mechanical residuals removal equipment shall be provided in the sedimentation basin; and
    2. Provisions must be included for proper disposal of softening residuals in accordance with regulations in 10 CSR 20;

j. Disinfection. The use of excess lime is no substitute for disinfection; and

k. Plant start-up. The plant processes must be manually started following shutdown, unless approved by the department where automatic monitoring controls are provided.

4.5.2. Cation exchange process.

a. Alternative methods of hardness reduction should be investigated when the sodium content and dissolved solids concentration are of concern.

b. Pre-treatment requirements. Iron, manganese, or a combination of the two, should not exceed 0.3 milligram per liter in the water as applied to the ion exchange resin. Pre-treatment is required when the content of iron, manganese, or a combination of the two, is one milligram per liter or more (see Section 4.6). Waters having five units or more turbidity should not be applied directly to the cation exchange softener.

c. Design. The units may be of pressure or gravity type, of either an upflow or downflow design. Automatic regeneration based on volume of water softened should be used unless manual regeneration is justified and is approved by the department. A manual override shall be provided on all automatic controls.

d. Exchange capacity. The design capacity for hardness removal should not exceed 20,000 grains per cubic foot when resin is regenerated with 0.3 pound of salt per kilograin of hardness removed.

e. Depth of resin. The depth of the exchange resin should not be less than three feet.

f. Flow rates. The rate of softening should not exceed seven gallons per minute per square foot of bed area and the backwash rate should be six to eight gallons per minute per square foot of bed area. Rate-of-flow controllers or the equivalent must be installed for the above purposes.

g. Freeboard**.** The freeboard will depend upon the specific gravity of the resin and the direction of water flow. Generally, the wash water collector should be 24-inches above the top of the resin on downflow units.

h. Underdrains and supporting gravel. The bottoms, strainer systems and support for the exchange resin shall conform to criteria provided for rapid rate gravity filters.

i. Brine distribution. Facilities should be included for even distribution of the brine over the entire surface of both upflow and downflow units.

j. Cross connection control. Backwash, rinse, and air relief discharge pipes must be installed in such a manner as to prevent any possibility of back-flow.

k. Bypass. A bypass must be provided around softening units to produce a blended water of desirable hardness. Totalizing meters must be installed on the bypass line and on each softening unit. The bypass line must have a shut-off valve and should have an automatic proportioning or regulating device. In some installations, it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.

l. Additional limitations. Silica gel resins should not be used for waters having a pH above 8.4 or containing less than 6 milligrams per liter silica and should not be used when iron is present. When the applied water contains a chlorine residual, the cation exchange resin shall be of a type that is not damaged by residual chlorine. Phenolic resin should not be used.

m. Sampling taps. Sampling taps must be provided for the collection of representative samples. Petcocks are not acceptable as sampling taps. The taps shall be located to provide for sampling of the softener influent, effluent and blended water. The sampling taps for the blended water shall be at least 20 feet downstream from the point of blending when a static mixer is not provided. Sampling taps should be provided on the brine tank discharge piping.

n. Brine and salt storage tanks.
   1. Salt dissolving or brine tanks and wet salt storage tanks must be covered and must be corrosion-resistant.
   2. The make-up water inlet must be protected from backflow. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.
   3. Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or railcar. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs.
   4. Overflow, where provided, must be protected with a corrosion resistant screen and must terminate with either a turned-down bend having a proper free fall discharge or a self-closing flap valve.
   5. Two wet salt storage tanks or compartments designed to operate independently should be provided.
   6. The salt shall be supported on graduated layers of gravel placed over a brine collection system.
   7. Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered.

o. Salt and brine storage capacity. Total salt storage should have sufficient capacity to store in excess of 1½ carloads or truckloads of salt, and provide for at least 30 days of operation.

p. Brine pump or eductor. An eductor may be used to transfer brine from the brine tank to the softeners. If a pump is used, a brine measuring tank or means of metering should be provided to obtain proper dilution.

q. Stabilization. Stabilization for corrosion control shall be provided. An alkali feeder shall be provided except when exempted by the department.

r. Waste disposal**.** Disposal of brine waste must be in accordance with Clean Water Commission Regulations.

s. Construction materials. Pipes and contact materials must be resistant to the aggressiveness of salt. Epoxy coated ductile iron pipe and fittings with flanged mechanical joints and stainless steel bolts is the preferred material. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine. Plastic and red brass are acceptable piping materials provided the following is considered:

1. Using plastic pipe as a softener or production piping creates design issues that must be addressed before an approval will be issued. Major failure of plastic pipe fittings due to fatigue stress has occurred when it was used as softener and process piping.
2. Plastic fittings should not be used in high pressure conditions such as when operating pressures regularly exceed 50 PSI.
3. Anchors, blocking and other devices must be installed to prevent movement and to minimize vibration of plastic pipe and fittings.
4. Solvent weld joints shall not be used for piping greater than 2-inches in diameter.
5. Flanged mechanical joint pipe with stainless steel bolts should be used for piping greater than 2-inches in diameter.
6. Threaded joints shall not be used for plastic pipe or fittings.
7. Schedule 120 or equal strength fittings and pipe should be used.

t. Housing. Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas in order to prevent damage to equipment.

Deleted: Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine.

4.6. Aeration.

Aeration may be used to help remove offensive tastes and odors due to dissolved gases from decomposing organic matter, or to reduce or remove objectionable amounts of carbon dioxide, hydrogen sulfide, etc., and to introduce oxygen to assist in iron and/or manganese removal. The design criteria in this section are not intended for removal of organics.

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4.6.1. Forced or induced draft aeration.

Induced draft aeration is preferred. Natural draft aeration shall not be approved. Forced or induced draft aeration devices shall:

a. Include blowers with weatherproof motors in weathertight housings and screened enclosures that will provide a combined flow 3.5 to 6 cubic feet of air per minute for each gallon per minute of water flow;
b. Insure adequate counter current of air through the enclosed aerator column;
c. Exhaust air directly to the outside atmosphere;
d. Include down-turned and 18-mesh screened air outlets and inlets. Screens over air inlets shall be easily removed for cleaning and shall be located where they can be easily accessed and inspected;
e. Be designed such that air introduced in the column shall be as free from obnoxious fumes, dust, and dirt as possible;
f. Be designed such that one side or a portion of one side may be easily opened for inspection and maintenance of the interior of the aerator by hinged doors or panels, secured with latches, and located so that all aspects of the aerator are easily accessible for maintenance, and be provided with provisions for safely removing and lowering the trays or media to the ground, and the replacement of the trays or media;

g. Provide loading at a rate of one to five gallons per minute for each square foot of total tray area;
h. Insure that the water outlet is adequately sealed to prevent unwarranted loss of air;
i. Discharge through a series of five or more trays with separation of trays not less than six inches;
j. Provide distribution of water uniformly over the top tray. Non metallic nozzles to prevent plugging of the distributor openings are recommended. Access ways shall be provided to allow routine cleaning of the entire distributor, its openings and all distribution nozzles;
k. Be resistant to the aggressiveness of the water and dissolved gases;
l. Provide a bypass line around the aerator to allow plant operation to continue while the aerator is removed from service for maintenance or cleaning and to facilitate disposal of iron residue during cleaning;

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m. When located on raised platforms or mounted on top of basins, sufficient work area with safety railings shall be provided around the perimeter of the aerator to provide safe access for inspection and maintenance. Access to the aerator work area shall be by stairs or walkways. Sufficient work area shall be provided in front of the access doors to the aerator interior to allow interior screens or media to be cleaned or replaced. Sufficient work area shall be provided to allow erection of ladders to safely access blowers
n. Not be located inside a building; and
o. Be constructed of stainless steel or aluminum.
p. Be provided with a suitably sized and configured contact basin to allow contaminants oxidized by the aeration to settle out before the water enters the treatment plant.

4.6.2. Pressure aeration.

Pressure aeration may be used for oxidation purposes only if pilot plant study indicates the method is applicable. It is not acceptable for removal of dissolved gases. Filters following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall be designed to:
a. Give thorough mixing of compressed air with water being treated;
b. Provide screened and filtered air, free of obnoxious fumes, dust, dirt, and other contaminants;
c. Have the necessary delivery capacity of air at 5 psi to 10 psi pressure, depending upon depth of water in the basin;
d. Give a detention period of 5 to 15 minutes based on design flow; and
e. Provide from 0.005 cubic foot to 0.2 cubic foot per gallon of water aerated.

4.6.3. Spraying.

a. Distribute water through spray nozzles with a pressure of approximately ten psi at the throat;
b. The area covered by the spray from each nozzle from about 10 to 200 square feet;
c. The output per nozzle from 40 to 175 gallons per minute, depending upon the type of nozzle; and

d. Protection from loss of spray water by wind carriage by enclosure with louvers sloped to the inside at an angle of approximately 45 degrees.

4.6.4. Other methods of aeration.

Other methods of aeration may be used if applicable to the treatment needs, subject to the approval of the department.

4.6.5. Protection of aerators.

All aerators except those discharging to lime softening or clarification plants shall be protected from contamination from birds, insects, and windborne debris.

4.6.6. Disinfection.

Groundwater supplies exposed to the atmosphere by aeration must receive chlorination as the minimum additional treatment.

4.6.7. Bypass.

A bypass shall be provided for all aeration units.

4.6.8. Corrosion control.

The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary.

4.7. Iron and Manganese Control

Iron and manganese control, as used in this section, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment process must meet specific local conditions as determined by engineering investigations, including chemical analysis of representative samples of water to be treated, and receive the approval of the department. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design. Allowances must be made for deterioration of groundwater quality, over time, and for variations in ground water quality at different locations. Testing equipment and sampling taps shall be provided as specified in sections 2.8 and 2.10**.**

4.7.1. Removal by oxidation, detention and filtration.

a. Oxidation.
   Oxidation may be by aeration, as indicated in Section 4.6 or by chemical oxidation with chlorine, potassium permanganate, ozone, or chlorine dioxide. For systems with iron, manganese or combined concentrations greater than 15 mg/l or organic bound iron or manganese, provisions shall be made for feeding additional oxidants after aeration.
b. Detention.
   Facilities that provide aeration must provide disinfection with at least sufficient disinfection contact time to meet 4-log inactivation or removal of viruses. Disinfection contact time may be provided in the detention or settling basin following aeration.

1. Reaction-A minimum detention time of two hours shall be provided following aeration for water containing iron or manganese to insure that the oxidation reactions are as complete as possible. This minimum detention time may be decreased only where indicated by a pilot plant study. The detention basin shall be designed with sufficient baffling to minimize short-circuiting.
   a. Provisions shall be made for adding chemicals for pH adjustment and enhancement of the oxidation process.
   b. Provisions shall be made for providing rapid mixing time of 30 seconds.
   c. For systems with combined iron and manganese concentrations greater than 10 mg/l present in the raw water, coagulant feed and flocculation facilities should be provided.
   d. Covered detention basins requiring manual residuals removal shall be provided with equipment to safely vent the basins during cleaning.
2. Sedimentation-A sedimentation basin in place of a detention basin shall be provided when treating water containing 4 mg/L or more iron and/or manganese, or where chemical coagulation is used to reduce the load on the filters. Provisions shall be made for adding chemicals for pH adjustment and enhancement of the oxidation process. Coagulant addition and rapid mixing should also be provided. Facilities for rapid mixing flocculation and sedimentation should be designed in accordance with section 4.1. Provisions for residuals removal shall be made. The detention basin shall be designed with sufficient baffling to prevent short-circuiting. The detention time in the sedimentation basin shall be based on the total concentration of iron and/or manganese in the water to be treated.
   a. The following are the minimum detention times at different concentration ranges of iron and /or manganese exceeding 4 mg/L:
      1. 4mg/L to 9 mg/L - four hours detention time;
      2. 10mg/L to 20mg/L - six hours detention time; and
      3. Above 20 mg/L – to be determined from pilot or full-scale demonstration plant study.
   b. The following provisions shall be included for combined reaction and sedimentation basins:
      1. Provisions shall be made for adding chemicals for pH adjustment and enhancement of the oxidation process.
      2. Provisions shall be made for adding a coagulant; and
      3. Provisions shall be made for providing rapid mix of 30 seconds.

4.7.2. Removal by the lime-soda softening process.

Iron and manganese removal is not always incidental to lime softening. When the raw water contains concentrations of iron or combined concentrations of iron and manganese of 20 mg/l or greater or contains organic bound iron or manganese, additional treatment processes may be needed to assure adequate removal of the iron or manganese. See paragraph 4.5.1.

4.7.3. Removal by manganese greensand, manganese coated or other propriety filter media.

1. This process consists of a continuous feed of potassium permanganate or other oxidizing chemical to the influent of a filter. Pilot studies must be done to obtain department approval.
2. Provisions should be made to apply the permanganate as far ahead of the filter as practical and to a point immediately before the filter.
3. Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the cost of the chemical.
4. Anthracite media cap of at least six inches shall be provided over manganese greensand.
5. Normal filtration rate is three gallons per minute per square foot.
6. Normal wash rate is eight to ten gallons per minute per square foot with manganese greensand and 15 to 20 gallons per minute per square foot with manganese coated media, or as recommended by the media manufacturer.
7. Air washing should be provided.
8. Sample taps shall be provided:
   a. Prior to application of permanganate;
   b. Immediately ahead of filtration; and
   c. At the filter effluent.
9. Sample taps should be provided:
   a. At a point between the media layers; and
   b. Halfway down the media when only one type media is utilized.

4.7.4. Removal by ion exchange.

This process of iron and manganese removal should not be used for water containing more than 0.3 milligram per liter of iron, manganese or combination thereof. This process is not acceptable where either the raw water or wash water contains dissolved oxygen.

4.7.5. Sequestration by polyphosphates.

1. This process shall not be used when iron, manganese, or combination thereof exceeds 1.0 milligram per liter. The total phosphate applied shall not exceed 10 milligrams per liter as orthophosphate. Where phosphate treatment is used, provisions for continuous disinfection of the water with free available chlorine shall be provided. Possible adverse affects on corrosion must be addressed when phosphate addition is proposed for iron sequestering. Polyphosphate treatment may be less effective for sequestering manganese than for iron.
2. The effectiveness of polyphosphate to sequester iron is affected by the concentration of calcium in the water. More polyphosphate is needed as the calcium hardness of water increases. Bench tests should be done in water with calcium hardness of 100 mg/l and higher to determine the optimum polyphosphate dose. Design of polyphosphate feeding facilities shall provide a sufficient feed range to adjust to the optimum dose.

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3. Design shall provide for polyphosphate addition with adequate dispersion in the water prior to the addition of chlorine. A minimum 30 second contact time should be provided before chlorine is added.
4. Laboratory testing equipment shall be provided to routinely test the water for total phosphate and orthophosphate.
5. Feeding equipment shall conform to the requirements of Chapter 5 of this document.
6. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 milligrams per liter free chlorine residual in the stock solution.
7. Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to any aeration, oxidation, or disinfection if no iron or manganese removal treatment is provided.
8. Phosphate chemicals must be acceptable to the department.
9. Orthophosphate is a nutrient, so many wastewater treatment plants are limited in the amount of orthophosphate they can discharge to the receiving stream. It is important to check with the wastewater treatment plant to establish proper limits for the phosphate dosage.

4.7.5. Sequestration by sodium silicates.

Sequestration with silicates is temporary in nature. Systems that have detention times longer than 1.4 days in storage or water mains must develop procedures and install provisions to remove the precipitate and colored water.

Sodium silicate sequestration of iron and manganese is appropriate only to groundwater supplies prior to air contact. On-site pilot tests are required to determine the suitability of sodium silicate for the particular water and the minimum dose needed.

1. Silicate sequestration operates only on oxidized forms of metals. Sufficient chlorine must be added to oxidize the iron and provide a free residual. Chlorination must precede the introduction of sodium silicate. Addition of sodium silicate must be within 15 seconds after the addition of chlorine.
2. Sodium Silicate addition is applicable to waters containing up to 2 mg/L of iron, manganese or combination thereof. Manganese is poorly treated by sodium silicate and problems may be encountered with manganese concentrations slightly above the 0.5 mg/l maximum contaminant level.
3. Laboratory testing equipment shall be provided to routinely test the water for total silica.
4. Equipment must be provided so that chlorine residuals recommended in section 4.4.2 can be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron.
5. The amount of silicate added shall be limited to 20 mg/L as $Si0_2$. The amount of added and naturally occurring silicate shall not exceed 60 mg/L as $Si0_2$.
6. Feeding equipment shall conform to the requirements of Chapter 5 of this document.
7. Sodium silicate shall not be applied ahead of iron or manganese removal treatment.
8. Quality of sodium silicate must be acceptable to the department.

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4.8. Control of Organic Contamination.

Controlling organic contamination is an area of design that requires pilot studies and early consultation with the department. Where treatment is proposed, the best available technology shall be provided to reduce organic contaminants to the lowest practical levels.

4.8.1. Engineering Report.

Except for temporary, emergency treatment conditions, particular attention shall be given to developing an engineering report that, in addition to the normal determinations in section 1.1, includes the following:

a. Types of organic chemicals, sources, concentrations, frequency of occurrence if in surface water or estimated residence time within the aquifer and flow characteristics if in ground water, water pollution abatement schedule, etc.;
b. Possible treatment alternatives;
c. Results of bench, pilot, or full scale testing, demonstrating the effectiveness and cost of the treatment alternatives; and
d. A determination of quality and/or operational parameters which may serve as the best measurement of treatment performance, and a corresponding monitoring and process control program.

4.8.2. Control Alternatives.

In general, the design of control and treatment alternatives for organic contamination requires pilot or full scale testing. Collection of data pertinent to design is often complicated and lengthy. A permanent engineering solution for organic contamination may take significant time to develop. The following alternatives should be considered:

a. Alternative source development or purchase of water from nearby unaffected water systems may be a more expedient solution;
b. Alterations of existing treatment to enhance organic removal;
c. Adsorption by granular activated carbon. See section 4.8.2.1.
d. Air stripping for volatile organics. See section 4.8.2.2.

4.8.2.1. Considerations for adsorption by granular activated carbon

Consideration should be given to:

1. Determining the filter isotherm for the particular contaminant to be removed, and the minimum contact time with the carbon bed that is necessary for removing the contaminant;
2. Using contact units rather than replacing portions of existing filter media;
3. Series and parallel flow piping configurations to minimize the effect of breakthrough without reliance on continuous monitoring;
4. Providing at least two units. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved rate. Where more than two units are provided, the contactors shall be capable of meeting the design capacity at the approved rate with one (largest) unit out of service;
5. Using virgin carbon. Although reactivated carbon may present an economic advantage at large water treatment plants, such an alternative may be

Deleted: Air stripping for volatile organics.

Deleted: In designing the air stripping tower, consideration should be given to:¶
1. Materials for tower, packing, and piping that are acceptable for use in contact with potable water;¶
2. Providing a moisture barrier (de-mister);¶
3. Metering the water flow to the tower;¶
4. Metering the air flow to the tower;¶
5. Providing influent and effluent sampling taps;¶
6. Disinfecting the water passing through the tower;¶
7. Designing the tower and air to water ratio to reduce the critical contaminants to the lowest practical level;¶
8. The air discharge meeting the air quality standards of the Missouri Air Conservation Commission;¶
9. Provision for easy inspection, maintenance, and cleaning of the packing materials. Iron and manganese pre-cipitation, carbonate deposition, and biological fouling are potential problems;¶
10.Chemical stability of the finished water; and¶
11.Acceptable supply during periods of maintenance and operation interruptions; and

Deleted: Adsorption by granular activated carbon. Consideration should be given to:¶
1. Determining the filter isotherm for the particular contaminant to be removed, and the minimum contact time with the carbon bed that is necessary for removing the contaminant;¶
2. Using contact units rather than replacing portions of existing filter media;¶
3. Series and parallel flow piping configurations to minimize the effect of breakthrough without reliance on continuous monitoring;¶
4. Providing at least two units. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved rate. Where more than two units are provided, the contactors shall be capable of meeting the design capacity at the approved rate with one (largest) unit out of service; ¶
5. Using virgin carbon. Although reactivated carbon may present an economic advantage at large water treatment plants, such an alternative may be pursued only with the preliminary endorsement of the department. If regenerated carbon is accepted, only carbon previously used for potable water treatment can be used for this purpose. Transportation and regeneration facilities must not have been used for carbon put to any other use; and¶
6. Acceptable means of spent car ... [1]

pursued only with the preliminary endorsement of the department. If regenerated carbon is accepted, only carbon previously used for potable water treatment can be used for this purpose. Transportation and regeneration facilities must not have been used for carbon put to any other use; and

6. Acceptable means of spent carbon disposal, pursuant to hazardous waste management regulations in 10 CSR 25.

4.8.2.2. Considerations for stripping volatile organics with packed tower aeration

Packed tower aeration (PTA) involves passing water down through a column of packing material while pumping air counter-currently up through the packing. PTA is used for the removal of volatile organic chemicals, trihalomethanes, carbon dioxide, and radon. Generally, PTA is feasible for compounds with Henry's Constant greater than 100 ATM mol/mol at 12 ^{0}C, but not normally feasible for removing compounds with Henry's Constant less than 10. For values between 10 and 100, PTA may be feasible but should be extensively evaluated using pilot studies. Values for Henry's Constant should be discussed with the reviewing agency prior to final design.

a. Process design

1. Process design methods **shall determine** Henry's Constant for the contaminant, the mass transfer coefficient, air pressure drop and stripping factor. The applicant shall provide justification for the design parameters selected (i.e. height and diameter of unit, air to water ratio, packing depth, surface loading rate, etc.). Pilot plant testing may be required.
2. The pilot testing shall evaluate a variety of loading rates and air to water ratios at the peak contaminant concentration. Special consideration should be given to removal efficiencies when multiple contaminations occur. Where there is considerable past performance data on the contaminant to be treated and concentration levels are similar to previous projects, the reviewing authority may approve the process design based on use of appropriate calculations without pilot testing. Proposals of this type must be discussed with the department prior to submission of any permit applications.
3. The tower shall be designed to reduce contaminants to below the maximum contaminant level (MCL) and to the lowest practical level.
4. The ratio of the column diameter to packing diameter should be at least 7:1 for the pilot unit and at least 10:1 for the full scale tower. The type and size of the packing used in the full scale unit shall be the same as that used in the pilot work.
5. The minimum volumetric air to water ratio at peak water flow should be 25:1. The maximum air to water ratio for which credit will be given is 80:1.
6. The design should consider potential fouling problems from calcium carbonate and iron precipitation and from bacterial growth. It may be

necessary to provide pretreatment. Disinfection capability shall be provided prior to and after PTA.

7. The effects of temperature should be considered since a drop in water temperature can result in a drop in contaminant removal efficiency.

b. Water flow system

1. Water should be distributed uniformly at the top of the tower using spray nozzles or orifice type distributor trays that prevent short circuiting. For multi-point injection, one injection point for every 30 in^2 of tower cross-sectional area is recommended.
2. A mist eliminator shall be provided above the water distributor system.
3. A side wiper redistribution ring shall be provided at least every 10 feet in order to prevent water channeling along the tower wall and short circuiting.
4. Sample taps shall be provided in the influent and effluent piping.
5. The effluent sump, if provided, shall have easy access for cleaning purposes and be equipped with a drain valve. The drain shall not be connected directly to any storm or sanitary sewer.
6. A blow-off line should be provided in the effluent piping to allow for discharge of water/chemicals used to clean the tower.
7. The design shall prevent freezing of the influent riser and effluent piping when the unit is not operating. If piping is buried, it shall be maintained under positive pressure.
8. The water flow to each tower shall be metered.
9. An overflow line shall be provided which discharges 12 to 14 inches above a splash pad or drainage inlet. Proper drainage shall be provided to prevent flooding of the area.
10. Butterfly valves may be used in the water effluent line for better flow control, as well as to minimize air entrainment.
11. Means shall be provided to prevent flooding of the air blower.
12. The water influent pipe should be supported separately from the tower's main structural support.

c. Air flow system

1. The air inlet to the blower and the tower discharge vent shall be downturned and protected with a non-corrodible 24-mesh screen to prevent contamination from extraneous matter. It is recommended that a 4-mesh screen also be installed prior to the 24-mesh screen on the air inlet system.
2. The air inlet shall be in a protected location.
3. An air flow meter shall be provided on the influent air line or an alternative method to determine the air flow shall be provided.
4. A positive air flow sensing device and a pressure gauge shall be installed on the air influent line. The positive air flow sensing device shall be a part of an automatic control system which will turn off the influent water if

positive air flow is not detected. The pressure gauge will serve as an indicator of fouling buildup.
5. A backup motor for the air blower shall be readily available.

d. Other features that shall be provided
1. A sufficient number of access ports with a minimum diameter of 24 inches to facilitate inspection, media replacement, media cleaning and maintenance of the interior.
2. A method of cleaning the packing material when fouling may occur.
3. Tower effluent collection and pumping wells constructed to clearwell standards.
4. Provisions for extending the tower height without major reconstruction.
5. An acceptable alternative supply must be available during periods of maintenance and operation interruptions. No bypass shall be provided unless specifically approved by the reviewing agency.
6. Disinfection application points both ahead of and after the tower to control biological growth.
7. Disinfection and adequate contact time after the water has passed through the tower and prior to the distribution system.
8. Adequate packing support to allow free flow of water and to prevent deformation with deep packing heights.
9. Operation of the blower and disinfection equipment during power failures.
10. Adequate foundation to support the tower and lateral support to prevent overturning due to wind loading.
11. Fencing and locking gate to prevent vandalism.
12. An access ladder with safety cage and work platforms for inspection of the aerator including the exhaust port and de-mister.
13. Electrical interconnection between blower, disinfectant feeder and well pump.

e. Environmental factors
1. The applicant must contact the appropriate air quality office to determine if permits are required under the Clean Air Act.
2. Noise control facilities should be provided on PTA systems located in residential areas.

4.9. Stabilization.

Water that is unstable due either to natural causes or to subsequent treatment should be stabilized. Chemicals can be fed to provide a stable to slightly depositing water or to mitigate the solubility of targeted parameters. Regulation 10 CSR 60-4.070 sets secondary contaminant levels and requires that water be noncorrosive. Regulation 10 CSR 60-15.010 concerns lead and copper standards and requires that all water systems install and operate optimal corrosion control treatment. If the raw water is corrosive or if treatment is provided that causes corrosive water, corrosion control treatment shall be provided.

4.9.1. Carbon dioxide addition.

Carbon dioxide is generally fed at plants that lime-soften to stop the softening process and prevent excess deposition of calcium carbonate onto filters and in the water distribution system. Carbon dioxide storage and feeding facilities shall meet the requirements of Chapter 5 of this document.

4.9.2. Acid addition.

a. Feed equipment shall conform to Chapter 5 of this document.
b. Adequate precautions shall be taken for operator safety, such as the provision of personal protective equipment, transfer pumps and not adding water to concentrated acid.
c. If bulk storage is used, containment walls that will adequately hold the acid must be provided.

4.9.3. Phosphates.

a. The feeding of phosphates may be applicable for sequestering calcium in lime-softened water, corrosion control, and in conjunction with alkali feed following ion exchange softening. However, feeding phosphates is not acceptable as a substitute for proper operation and maintenance of the existing coagulation, filtration or recarbonation processes.
b. Feed equipment shall conform to Chapter 5 of this document.
c. Phosphate quality must be acceptable to the department.
d. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 milligrams per liter free chlorine residual.
e. Phosphates can act as a nutrient for biological growth in water distribution systems. Therefore, disinfection equipment shall be provided that is sufficient to maintain disinfectant residuals throughout the distribution system at levels necessary to control biological growths. Heterotrophic bacteria studies should be done routinely to assure that biological growths are controlled through out the distribution system.

4.9.4. Split Treatment.

Treatment plants designed to use "split treatment" should also contain facilities for further stabilization by other methods. A series of tests for iron and manganese shall be performed on all of the water sources before considering split treatment. Iron and manganese tests shall be done upon startup and throughout the pumping cycle of each source to find out if surges of high concentrations occur. Plants that soften surface water shall not blend water for stabilization. Because of deposition, all blending for stabilization shall be done before filtration and bench tests shall be done to determine if blending alone will sufficiently stabilize the water.

4.9.5. Alkali Feed.

Aggressive water created by ion exchange softening shall be neutralized by an alkali feed that does not contain sodium. Alkali feeding facilities shall be provided for all ion exchange water softening plants except when exempted by the department. Adequate rapid mixing of the alkali with the water flow shall be provided. Turbidity monitoring may be necessary to assure that the alkali feed does not make the water cloudy.

4.9.6. Carbon dioxide reduction by aeration.

The carbon dioxide content of aggressive water may be reduced by aeration. Tests shall be done and data submitted to assure that the type of aerator proposed will provide the carbon dioxide reductions desired.

4.9.7. Other treatment.

Other treatment for controlling corrosive water by the use of sodium silicate and sodium bicarbonate may be used with the written approval of the department. Any proprietary compound must receive the specific written approval of the department before use.

4.9.8. Water unstable due to biochemical action in distribution system.

Unstable water resulting from bacterial decomposition of organic matter biochemical action within tubercles, and reduction of sulfates to sulfides should be prevented by maintaining a free chlorine residual of 0.5 mg/L throughout the distribution system. This may be done by boosting chlorine residuals or by a program of routine water main flushing.

4.9.9. Control.

Laboratory equipment shall be provided for determining the effectiveness of stabilization treatment. The preferred method of determining stability is the calcium carbonate stability test using a continuous calcium carbonate contactor and pH, alkalinity, and calcium hardness analysis equipment.

4.10. Taste and Odor Control.

Provision shall be made for the control of taste and odor at all surface water treatment plants. Equipment for routine sampling and microscopic examination of the source water shall be available to the public water supply. Taste and odor removal chemicals shall be added sufficiently ahead of other treatment processes to ensure adequate contact time for an effective and economical use of the chemicals. Where severe taste and odor problems are encountered, in-plant or pilot plant studies, or both, are required.

4.10.1. Flexibility.

Plants treating water known to have taste and odor problems should have equipment that makes several control processes available so the operator will have flexibility in operation. At a minimum, equipment for feeding powdered activated carbon and potassium permanganate should be provided. In addition, plant design should provide for feeding these chemicals at multiple locations in the treatment process.

4.10.2. Chlorination.

Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved. Excessive potential disinfection byproduct production through this process should be avoided by adequate bench-scale testing prior to design.

4.10.3. Chlorine dioxide.

Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols. However, chlorine dioxide can be used in the treatment of any taste and odor that is treatable by an oxidizing compound. Provisions shall be made for proper generating, feeding, storing and handling of all chemicals associated with chlorine dioxide.

4.10.4. Powdered activated carbon.

Powdered activated carbon will readily remove permanganate, chlorine, and chlorine dioxide from water and must be fed where it will not interfere with the action of these chemicals. Flash mixing shall be provided at the carbon application point to assure an even dispersion of the carbon in the water. A minimum contact time of 20 minutes is recommended with slow mixing provided. The required rate of feed of carbon in a water treatment plant depends upon the tastes and/or odors involved. Provision should be made for adding from 0.1 mg/l up to at least 50 mg/l at the maximum design flow of the treatment facilities. When high doses (greater than 15 mg/l) of powdered activated carbon are added, additional coagulation, flocculation and settling may be required to reduce carbon loading on filters. Filtration shall be provided subsequent to the feeding of powdered activated carbon.

Deleted: should be added as early as possible in the treatment process to provide maximum contact time. Flexibility to allow the addition of carbon at several points is required. Activated carbon should not be applied near the point of chlorine application.

4.10.5. Granular activated carbon adsorption units.

See subparagraph 4.8.2.c.

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4.10.6. Copper sulfate and other copper compounds.

Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper concentrations more than 1.0 milligrams per liter as copper in the plant effluent or distribution system. Only compounds approved by the department for use with potable water may be used. Care shall be taken to assure an even distribution. Equipment for routine sampling and microscopic examination of the source water shall be provided at the water plant to assure that over treatment does not occur. Approved equipment to daily test for copper concentrations shall be provided.

4.10.7. Aeration.

Literature searches or pilot studies shall be done to assure that the particular taste and odor-causing compounds can be removed by aeration before submitting plans and specifications.

4.10.8. Potassium or sodium permanganate.

Application of potassium or sodium permanganate is recommended, providing the treatment shall be designed so that finished water manganese concentrations do not exceed the 0.05 mg/L secondary maximum contaminant level. Equipment to daily test for manganese concentrations shall be provided. Both potassium and sodium permanganate are readily adsorbed by activated carbon and cannot be fed in the same location. A minimum reaction time of 20 minutes is recommended. Because underfeeding permanganate will increase disinfectant byproducts, equipment shall be provided to perform permanganate demand tests and assure that optimum doses are fed.

Sodium permanganate is a very strong, highly reactive oxidant that requires special care in handling and feeding. A thorough understanding of sodium permanganate is required to design facilities that will protect the safety of the operators and the treatment facilities.

4.10.9. Ozone.

Ozonation can be used as a means of taste and odor control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors. Analyses for bromates should be done early in the design process. Biological mediation or other byproduct removal processes shall be included as a part of the ozone facility design.

4.10.10. Other methods.

The decision to use any other methods of taste and odor control shall be made only after careful laboratory and/or pilot plant tests and after obtaining the approval of the department.

4.11. Waste Handling and Disposal

Provisions shall be made for proper disposal of water treatment plant sanitary and process wastes such as discharges from water closets, urinals and lavatories and laboratory wastes, filter backwash water, brines and clarification, softening, iron and manganese residuals. All waste discharges are governed by regulatory agency requirements and shall be handled or treated to meet the applicable requirements. Additional permits and approvals other than those issued by the Missouri Public Drinking Water Program may be required. It is the responsibility of the water system officials or their representatives to submit all required applications, submittals, and permit fees to the appropriate agencies and to obtain all necessary permits.

All wastewater discharges shall meet the general water quality criteria in 10 CSR 20-7.031(3) and any additional criteria on the specific type of wastewater discharged. Treatment plant process residuals can be handled as a solid waste or through the wastewater permit process. If handled as a solid waste, residuals shall be hauled to a permitted sanitary landfill for disposal. Permanent residual storage makes the storage facilities a solid waste disposal site requiring the appropriate studies and permits. If handled through the wastewater permit process, residuals are land applied for agronomic purposes.

If the process residuals are to be land applied, those chemical characteristics that will affect its land application must be discussed as a part of the engineering report submitted to the department. Estimates of the amount of land required for disposal and of the years that the land can be used must be included. Process waste handling facilities shall be designed to be compatible with the drinking water treatment facilities and not adversely affect drinking water treatment. The process waste handling facilities must be designed to be compatible with the resources and capabilities of the specific system and its operators. Methods and equipment for efficiently removing and disposing of process waste must be part of the handling facility design. If land application is to be done by a contractor information must be submitted on the arrangements with a contractor to remove and land-apply the residuals. The method and information used in estimating the amount and type of process waste produced must be part of the engineering report submitted to the department. In locating waste disposal facilities due consideration shall be given to preventing potential contamination of water sources, treatment facilities, and raw and finished water piping.

4.11.1. Earthen Lagoons and Holding Basins.

All earthen lagoons and holding basins shall be designed and constructed to meet the requirements of 10 CSR 20-8.020(3) for design of small sewerage works for waste stabilization ponds and shall be provided with the following:

a. a location free from flooding or protected to a minimum one in ten year flood;
b. a means of diverting surface water so that it does not flow into the lagoons;
c. a minimum usable depth of five feet;
d. a minimum freeboard of two feet;
e. an adjustable decanting device;
f. influent and effluent facilities designed to minimize short circuiting through the lagoon;
g. an effluent sampling point; and
h. a method to prevent brush and weed growth on the interior slopes of the lagoon berm. If rip rap is used, it should have a minimum depth of 18-inches and extend from the toe of each berm to the top of the slope. The rip rap should be provided in at least two layers with the first 12-inches consisting of mixed rock 2-inches and smaller in diameter.

4.11.2. Sanitary waste.

a. Shall be discharged directly to a permitted sanitary sewer system, when feasible, or to an adequate on-site treatment facility approved by the department;
b. Shall not be discharged to a process waste lagoon or backwash water lagoon or to a residual holding basin or tank;
c. May be discharged to sewage holding tanks when site restrictions, geology, or soil type prevents using a wastewater lagoon or septic tank and tile field. Sewerage holding tanks must be routinely pumped out and the waste hauled to a permitted wastewater treatment facility for disposal. The name of the wastewater treatment facility where the waste will be hauled for disposal must be part of the submittal to the department. Holding tank location must provide for easy access by hauling equipment. Holding tanks must be equipped with the necessary devices to effectively access and remove the waste from the holding tank.
d. Laboratory sample taps that run continuously while the plant is in operation can be discharged to a backwash holding basin or residuals lagoon by means of drainage that is separate from the laboratory sink and plant sanitary sewerage piping system.

4.11.3. Brine waste.

Brine waste from ion exchange plants, demineralization plants, or other plants that produce brine waste may be discharged to:

a. Sanitary sewers with the approval of the local wastewater system authority; or

b. A flowing stream provided the stream flow is adequate to provide the necessary dilution.

4.11.4. Lime softening residuals

Lime softening residuals may be land applied at agronomic rates. Residuals from plants using lime to soften water vary in quantity and in chemical characteristics depending on the softening process and the chemical characteristics of the water being softened. These characteristics govern the amount of residual that can be applied to any specific piece of ground. A major factor limiting the amount of residuals that can be land applied is the aluminum content of the residuals. The source of aluminum in most lime softening residuals is the coagulants fed during treatment. This issue shall be considered when designing the coagulant feeding facilities for the treatment plant. The engineering report submitted to the department shall include a discussion of the expected residual characteristics. Methods of treatment and disposal are as follows:

a. Lagoons may be used to temporarily store residuals until they can be removed for final disposal. Storage lagoon(s):
   1. Must be designed to be cleaned periodically;
   2. Submittals shall include descriptions and specifications on residuals removal, handling, processing and disposal equipment or shall include information on the arrangements with a contractor to remove and land-apply the residuals.
   3. Submittals shall include a copy of facility specific, standard, operating procedures for residual removal and disposal. The operating procedures shall include a discussion of the manpower necessary for proper operation of the facilities;
   4. Shall be designed to provide a total of at least six months of residual storage calculated on the basis of 3.5 pounds of dry residuals produced for each pound of lime fed and a usable lagoon depth of at least five feet. Where enhanced softening for organics removal is proposed, larger amounts of residuals is produced. An alternative design may be based on an annual requirement of 1.0 acre-feet of lagoon per 100 mg/l of hardness removed per million gallons of water treated;
   5. Must have at least two but preferably more, storage cells in order to give flexibility in operation; and
   6. Shall be designed to produce a wastewater effluent that meets the Missouri Clean Water Commission effluent and water quality standards and that is satisfactory to the department.

b. Discharge of lime residuals to sanitary sewers should be avoided since it may cause both liquid and residual volume problems at the sewage treatment plant and sewer plugging problems. This method shall be used only when the sewerage system has adequate capacity and ability to handle the lime residuals.

c. Disposal at a permitted sanitary land fill can be done as either a solid or liquid if the landfill can and will accept such waste, in accordance with solid waste management regulations.

d. Mixing of lime residuals with waste activated residuals may be considered as a means of co-disposal. All necessary approvals from the local wastewater system

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operating authority shall be obtained. Pilot studies or trial runs to determine the impact of the lime residuals on the wastewater treatment facilities are recommended.

e. Mechanical drying of residuals may be considered. Pilot studies on a particular plant waste are required.

f. Calcination of residuals may be considered. Pilot studies on and detailed analyses of a particular plant waste are required.

g. Lime residual drying beds shall be constructed according to 10 CSR 20-8.170(8) for residuals drying beds

4.11.5. Clarification and Coagulation Residuals

An acceptable means of final residual disposal shall be provided as a part of the facility design and included in the engineering report. Clarification and coagulation residuals handling and disposal may consist of any of the following:

a. Mechanical concentration: A pilot plant study is required to design a mechanical residuals concentration installation. An engineering report explaining the findings and including data verifying the results of the pilot study shall be provided as a part of the Application for Construction Approval;

b. Freezing: Freezing changes the nature of clarification/coagulation residuals and allows it to be dried. Missouri weather does not allow natural freezing to be used as a reliable method and the department will not approve a proposal depending on natural freezing. A pilot study shall be done to design a residuals freezing installation. An engineering report explaining the findings and including data verifying the results of the pilot study shall be provided as a part of the Application for Construction Approval;

c. Acid treatment: Acid treatment of residuals for alum recovery has been done in some large water systems. Because acid dissolution is non-selective and will release natural organic matter, iron, heavy metals, and other contaminants present in the residuals, bench top or pilot studies must be done and the product produced analyzed to determine if undesirable chemicals will be produced. An engineering report explaining the findings and including results of all analyses must be submitted as a part of the Application for Construction Approval. These contaminants must be removed before the recovered alum can be used in drinking water treatment;

d. Discharge to sanitary sewer: Clarification/coagulant residuals may be discharged directly to a sanitary sewer if the wastewater treatment facilities are designed to remove and process the residuals. Because the residuals are not biodegradable and will settle and interfere with their operation, the department will not approve discharging residuals to systems using wastewater stabilization ponds or to wastewater plants using mechanical treatment unless they have facilities to remove the residuals before the biological treatment processes. The following shall be done to obtain an approval to discharge process residuals to a sanitary sewer system:

    1. Obtain a letter of approval from the owner or operating authority of the sewerage system and submit a copy to the department;
    2. Submit an engineering report explaining the impact of the residuals on the

wastewater treatment facility and its residuals drying and handling facilities;

3. Submit evidence that the wastewater collection system, the wastewater treatment facilities and its residuals handling facilities are capable of handling the additional hydraulic and solids loading;
4. Because clarification / coagulant residuals may reduce the ability to dry bio-solids, pilot studies should be done to determine the ability of the wastewater facilities to handle the combined residuals; and
5. A holding basin for controlled discharge may be required; and

e. Lagoons: Lagoons may be used as a method of temporarily storing clarification/coagulant residuals.

1. Lagoons shall be designed to produce an effluent that meets the Missouri Clean Water Commission effluent and water quality standards and that is satisfactory to the department.
2. Lagoon size shall be calculated using the total amount of chemicals used plus a factor for turbidity. Unless justification is submitted for using another method clarification/coagulant residuals volume shall be calculated using the following formula:

$$S\ lb/mg = 8.34\ lb/gal \times ((D\ mg/L \div 4) + Turbidity\ NTU + PAC\ mg/L)$$

S lb/mg = Residual solids in pounds per million gallons of raw water pumped
D mg/L = Coagulant dosages in milligrams per liter
Turbidity NTU = average raw water turbidity
PAC mg/L = powdered activated carbon dosage in milligrams per liter.

To get the total volume of residuals, this product must be divided by the percent solids of the residuals. Total lagoon capacity shall provide at least six months of residual storage. When the residual lagoons are used for both residuals storage and filter backwash handling, the total capacity shall provide at least 12 months of storage.

3. Lagoons must have at least two, but preferably more, storage cells in order to give flexibility in operation.

4.11.6. Iron and Manganese Residuals and Wastewater.

Iron and manganese waste are regulated under the Missouri Clean Water Commission regulations by effluent limits set on iron and manganese concentrations. Waste filter wash water and settling basin residuals from iron and manganese removal plants may be processed and disposed of as follows:

a. Sand drying filters may be used to process waste filter wash water and settling basin residuals from treatment units that have automatic residual removal facilities. Sand filters shall have the following features:

1. Total filter area, regardless of the volume of water to be handled, should be no less than 100 square feet. Unless the filter is small enough to be cleaned and returned to service in one day, two or more cells are required;

2. Filters shall have sufficient capacity to contain, above the level of the sand, the entire volume of wash water produced by washing of all the production filters in the plant;
3. Sufficient filter surface area should be provided so that, during any one filtration cycle, no more than two feet of backwash water will accumulate over the sand surface;
4. The filter shall not be subject to flooding by surface runoff or flood waters. Finished grade elevation shall be designed to facilitate maintenance, cleaning and removal of surface sand as required;
5. The filter media shall consist of a minimum of twelve inches of sand, three to four inches of supporting small gravel or torpedo sand and nine inches of gravel in graded layers. All sand and gravel shall be washed to remove fines;
6. Unless the design engineer submits information justifying different sand sizes, filter sand shall have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5;
7. Each filter shall be provided with an adequate under drain system to permit satisfactory discharge of filtrate;
8. Provision shall be made for the sampling of each filter effluent;
9. Overflow devices from the filters shall not be permitted;
10. Where freezing is a problem provisions should be made for covering the filters during winter months;
11. Filters shall not have a common wall with a compartment storing finished water but shall be separate structures. Filter piping shall not create an unprotected cross-connection; and
12. The provisions for the final disposal of the residuals shall be provided in the submittals to the department and the equipment or contractor arrangements necessary to remove and haul the residuals shall be specified.

b. Lagoons may be used to temporarily store residuals until they can be removed for final disposal. Lagoons shall have the following features:
   1. Be designed with a volume 10 times the total quantity of wash water discharged during any 24-hour period;
   2. A minimum usable depth of five feet;
   3. Length four times width and the width at least three times the depth, as measured at the operating water level;
   4. Outlet to be at the end opposite the inlet;
   5. Velocity to be dissipated at the inlet end; and
   6. The provisions for the final disposal of the residuals shall be provided in the submittals to the department and the methods and equipment necessary to remove and haul the residuals shall be specified.

c. Discharge to community sanitary sewer
   Iron and manganese residuals and wastewater can be discharged to a permitted community sanitary sewer if the wastewater treatment facilities are designed to remove and process the residuals. Because the residuals are not biodegradable and will settle and interfere with their operation, the department will not

approve discharging residuals to systems using wastewater stabilization ponds or to wastewater plants using mechanical treatment unless they have facilities to remove the residuals before the biological treatment processes. The following must be done to obtain an approval to discharge process residuals to a sanitary sewer system:

1. Obtain a letter of approval from the owner or operating authority of the sewerage system and submit a copy to the department;
2. Submit an engineering report explaining the impact of the residuals on the wastewater treatment facility and its residuals drying and handling facilities;
3. Submit evidence that the wastewater collection system, the wastewater treatment facilities and the residuals handling facilities are capable of handling the additional hydraulic and solids loading; and
4. A holding basin for controlled discharge may be required**.**

d. Recycling Iron and manganese wastewater
Recycling of supernatant or filtrate from iron and manganese waste treatment facilities to the head of an iron removal plant shall not be allowed.

4.11.7. Filter Backwash Water

a. May be discharged directly to a sanitary sewer under the following conditions.
   1. Approval from the owner or operating authority of the sewerage system must be obtained and proof of the approval must be submitted.
   2. The wastewater collection system and the wastewater treatment facilities must be capable of handling the hydraulic loading and evidence must be submitted to assure this.
   3. A holding basin for controlled discharge may be required.

b. Discharge to the waters of the state**.**
The waste wash water shall be treated to remove solids and chlorine residuals. Solids may be removed by gravity using a holding basin or lagoon. If sufficient holding time is provided, holding the wash water in a lagoon may allow the chlorine residual to be used up with no further treatment. Otherwise facilities must be provided to remove the chlorine residuals. Holding basins or lagoons shall have the following:
   1. discharge structures that have sluice gates or valves to easily control the discharge;
   2. a design that allows a dechlorinating chemical to be fed;
   3. a minimum volume of three times the total quantity of wash water expected to be discharged during any 24-hour period;
   4. a minimum water depth of three feet;
   5. a length four times width and the width a least three times the depth as measured at the operating water level;
   6. an outlet at the end opposite the inlet; and
   7. Velocity to be dissipated at the inlet end.

c. Recycling waste filter wash water and filter to waste water to the head of the treatment plant may be considered. Plants treating surface water or groundwater under the influence of surface water should not recycle waste filter wash water.

1. Holding basins or lagoons shall be sized to ensure that cleaning of other filters will not be delayed because of a full holding basin or lagoon. Unless the engineer can justify the use of other criteria, a holding basin or lagoon shall have a volume ten times the total quantity of wash water and filter to waste water required to clean one filter. Unless the engineer can justify the use of other criteria, a filter backwash shall be calculated at 20 gallons per minute per square foot for 15-minutes and filter to waste shall be calculated at 3 gallons per minute per square foot for 60-minutes.
2. The holding basin or lagoon shall not receive discharges from sanitary facilities (water closets, urinals, lavatories, floor drains, sinks, etc.)
3. Rate of recycling shall not exceed 10 percent of the raw water flow entering the plant regardless of the designed plant capacity.
4. To determine the rate of flow, a meter shall be provided in the recycle piping. The meter shall have a remote readout located in the plant operations area that reads rate of flow in gallons per minute.
5. To control rate of flow, a throttling valve or similar device shall be provided in the recycle piping.
6. Filter backwash shall not be recycled when it contains excessive algae, iron, manganese or other contaminants; when finished water taste and odor or colored water problems are encountered or when it may cause disinfection byproduct levels in the distribution system to exceed allowable levels.

4.11.8. Wastes from plants using Missouri or Mississippi River water

The Missouri Clean Water Commission regulation 10 CSR 20-7.015(2) states that the suspended solids that are present in the water and are removed during treatment and any additional suspended solids resulting from the treatment of the water may be discharged to the Missouri River or the Mississippi River if the raw water source is:

a. Missouri River or Mississippi River waters.
b. Alluvial wells along the banks of the Missouri River or Mississippi River.

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Chapter 5 -- Chemical Application

5.0 GENERAL.

No chemicals shall be applied to treat drinking water unless specifically permitted by the department. All chemicals used to treat drinking water shall be certified for drinking water use in accordance with ANSI/NSF Standard 60/61.

5.0.1. Plans and specifications.

Plans and specifications shall be submitted for review and approval, as provided for in Chapter 5 of this document. Because specifications for chemical feeding equipment are generally performance specifications that give feed ranges and generic descriptions, detailed manufacturers' information on the equipment actually installed must be provided to obtain the required Final Construction Approval from the department. Plans and specifications shall include:

a. Descriptions of feed equipment, including maximum and minimum feed ranges;
b. Location of feeders, piping layout and points of application;
c. Storage and handling facilities;
d. Specific chemicals to be used;
e. Descriptions of the feed system including all tanks with capacities, (with drains, overflows, and vents), feeders, transfer pumps, connecting piping, valves, points of application, backflow prevention devices, air gaps, secondary containment, and safety eye washes and showers;
f. Operating and control procedures including proposed application rates and the results of chemical analyses, historic dosages, and the basis for choosing the proposed application rates, provided in the engineering report or as an appendix to the specifications; and
g. Description of testing equipment.

5.0.2. Chemical application.

Chemicals shall be applied to the water at such points and by such means to:

a. Ensure maximum efficiency of treatment;
b. Ensure maximum safety to consumer;
c. Provide maximum safety to plant personnel;
d. Ensure satisfactory mixing of the chemicals with the water;
e. Provide maximum flexibility of operation through various points of application, when appropriate;
f. Prevent backflow or backsiphonage from chemical feed pumps or between multiple points of feed through common manifolds;
g. Prevent any spillage of chemical into the mixing basin or settling basin. When chemical storage or feeders are located on top of the mixing and/or settling basin, a 4-inch to 6-inch curb shall be constructed around all the basin openings. Chemical feed or storage facilities shall not be located on top of pumping wells, transfer wells or clearwells unless specifically approved by the department. Where solution tanks, bulk tanks or day tanks are in locations where the contents could drain to the water being treated, complete spill containment shall be

provided;
h. Prevent the accidental overfeed of chemicals by using sufficient controls to prevent accidental chemical application when water is not being produced; and
i. Minimize interference and undesirable reactions between chemicals.

5.0.3. General equipment design.

General equipment design shall be such that:

a. Feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate throughout the range of feed;
b. Chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical fed and its solutions;
c. Chemical solutions injected into pipes are evenly dispersed throughout the water flow. Chemical solutions should be injected only in pipes that normally flow full of water;
d. Corrosive chemicals are introduced in such a manner as to minimize potential for corrosion and damage to water piping, treatment basins, and the water treatment facilities;
e. Chemicals that are incompatible are not fed, stored, or handled together;
f. All chemicals are conducted from the feeder to the point of application in separate conduits;
g. Chemical feeders are as near as practical to the feed point;
h. Chemical feeders and pumps operate at a setting no lower or higher than recommended by the manufacturer, or no lower than 20 percent or higher than 80 percent of rated maximum, whichever is more restrictive. If two fully independent adjustment mechanisms such as pump pulse rate and stroke length are provided then the pump shall be designed to operate at no lower than 10 percent and no higher than 90 percent of the rated maximum;
i. Normal chemical feed rate should be 50 percent of rated maximum;
j. Chemicals are fed by gravity where practical; and
k. Adequate space is provided around each chemical feeder to safely load, operate, clean, and maintain each feeder.

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5.0.4. Chemical Information.

For each chemical, the information submitted shall include:

a. specifications for the chemical to be used;
b. purpose of the chemical;
c. proposed minimum, average and maximum dosages, solution strength or purity (as applicable, and specific gravity or bulk density; and
d. method for calculation of amount fed daily.

5.1. FACILITY DESIGN.

5.1.1. Number of feeders.

a. Where chemical feed is necessary for the production of safe drinking water, such as chlorination, coagulation, or other essential processes:

1. A minimum of two feeders shall be provided or a standby unit or a combination of units of sufficient capacity shall be available to replace the largest unit during shut-downs; and
2. Where a booster pump or a transfer pump is required, duplicate equipment shall be provided and, when necessary, standby power.

b. A separate feeder shall be used for each chemical applied and should be used for each application point. Where one feeder is used to supply multiple application points, equipment shall be provided to accurately proportion and measure the amount of chemical fed at each application point. Only one solution pump should draw from a solution tank, day tank, barrel, or carboy.

c. Spare parts shall be available for all feeders to replace parts that are subject to wear and damage.

5.1.2. Control.

a. Feeders may be manually or automatically controlled. Automatic controls shall be designed to allow override by manual controls and to allow adjustment of each control parameter.

b. When automatic controls are used, they shall include devices that prevent feeders from operating unless water is being produced. Devices shall include, but may not be limited to, linking chemical feed units to source water pump controls and flow switches, and flow pacers where appropriate;**.**

c. When automatic controls are used, they shall include devices so that chemical feed rates shall be proportional to flow.

d. A means to measure all appropriate water flows must be provided in order to determine chemical feed rates.

e. Provision shall be made for measuring the volume or weight of chemicals used.

f. Weighing scales:

1. For weighing all barrels, carboys, or gas cylinders smaller than one ton in size shall be low profile for ease of loading onto the scales. Otherwise, electric hoists, hoist tracks and properly sized clamps or other mechanized loading equipment shall be provided;
2. Shall be provided for weighing all active gas cylinders at all plants utilizing chlorine gas, carbon dioxide, or ammonia gas;
3. Shall be required for fluoride solution feed;
4. Shall be provided for each active chemical solution day tank;
5. Shall be provided for each solution or emulsion fed from carboys or barrels;
6. Shall be provided to weigh chemicals when making batches of chemical feed solutions**;**
7. Should be provided for volumetric dry chemical feeders;
8. Should be accurate to measure increments of 0.5 per cent of load; and
9. Totaling gas meters shall be provided to measure all gas chemicals fed from rail cars or bulk storage containers.

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5.1.3. Dry chemical feeders.

Dry chemical feeders shall:

a. Measure chemicals volumetrically or gravimetrically;

b. Provide adequate solution water and agitation of the chemical at the point where it is placed into a solution or slurry;

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c. Provide gravity feed of solution from each feeder where possible;

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d. Completely enclose chemicals to prevent emission of dust to the operating room;

e. Be located and designed to prevent lifting injuries when loading sacks of chemical into the feeder. The current OSHA or National Institute of Occupational Safety and Health (NIOSH) guidance for manual lifting should be followed;

f. Provide adequate space around each feeder to allow chemical pallets to be moved close to the feeder and minimize the distance that chemical bags or containers must be carried;

g. Have chemical hoppers sized to minimize loading frequencies to no more than once per eight-hour shift;

h. Not have bulk storage facilities that feed directly into the feed chamber but have a chemical hopper on the feeder that is large enough to minimize chemical fluidization;

i. Have vibrators and anti-bridging and caking equipment that is separate from those provided on the bulk storage facilities;

j. Have feeder shells and housings constructed of stainless steel, aluminum or a nonmetallic substance that fully enclose the chemical being fed to minimize chemical dust created by the feeding process;

k. Have dissolving facilities or solution tanks that are sized according to the amount of chemical to be fed. Undersized or oversized dissolving facilities or solution tanks shall be avoided; and

l. Have rate-of-flow meters on the water lines servicing each chemical feeder to control the amount of solution water going to each dry feeder.

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5.1.4. Chemical solution metering pumps.

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a. Positive displacement type solution feed pumps should be used to feed liquid chemicals, but should not be used to feed chemical slurries.

b. Bypass piping or other methods for accurately measuring the output of the chemical solution feeders shall be provided.

c. Graduated measuring chambers should be built into the feeder piping to allow the feeder output to be routinely checked.

d. Flow indicators should be installed on the discharge tubing.

e. Where off-gassing could cause the pump to lose prime, a bleed valve or other similar valve shall be provided for chemicals with tendencies to off-gas, such as hypochlorite solutions.

f. Pumps must be capable of operating at the required maximum rate against the maximum head conditions found at the point of injection.

g. Manual pressure release valves shall be provided at the discharge of each solution pump to allow for maintenance of solution lines.

h. Fittings and piping shall be provided to safely drain the solution lines before working on a pump.

i. Solution piping, tubing, pump heads, check valves, pump o-rings, fittings and other appurtenances shall be compatible with the chemical fed.

5.1.5. Chemical Solution metering pumps - Siphon control.

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Chemical solution feeders shall be installed such that chemical solutions cannot be siphoned into the water supply. Chemical solution feeders shall:

a. Assure discharge at a point of positive pressure;
b. Provide vacuum relief;
c. Provide a suitable air gap; or
d. Provide diaphragm anti-siphon devices that are spring-loaded in the closed position on the discharge side of each metering pump head or other suitable means or combinations as necessary. When metering pump anti-siphon devices are provided, they should be selected to provide the backpressure required by the pump manufacturer. Peristaltic metering pumps do not require an anti-siphon device at the pump head but shall be equipped with a spring loaded check valve at the injector.

5.1.6. Backflow Prevention.

a. A department approved reduced pressure principle backflow prevention assembly shall be provided on the service line supplying water to the water treatment plant according to the requirements of 10 CSR 60-11.010.
b. Backflow prevention shall be provided to ensure that the service water lines discharging to solution tanks shall be properly protected from backflow.
    1. Air gap separation shall be two times the pipe diameter of the water line serving any chemical solution tank.
    2. Atmospheric vacuum breakers conforming to the latest American Society of Sanitary Engineering (ASSE) standard #1001, or AWWA/ANSI standard C512, shall be applied to water lines serving chemical solution tanks where no shut off or control valves are located downstream of the vacuum breaker.
    3. Pressure vacuum breakers conforming to the latest ASSE standard #1020 or AWWA/ANSI standard C512 shall be applied to water lines serving chemical solution tanks where shut off or control valves are located downstream of the vacuum breaker.
c. No direct connection shall exist between any sewer and a drain or overflow from a feeder, solution chamber or tank. All drains shall end at least six inches or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit or waste receptacle.

5.1.7. Chemical feed equipment location.

Unless otherwise approved by the department chemical feed equipment shall:

a. Be located in a properly vented separate room(s) to reduce hazards and dust problems;
b. Be conveniently located near points of application to minimize length of feed lines;
c. Be readily accessible for servicing, repair and observing operation;
d. Be located so as to provide feeding by gravity;
e. Be located in a well-lighted area such that additional lighting is not required for normal operation and maintenance;

f. Be located in areas provided with the drains, sumps, finished water plumbing and the hose bibs and hoses necessary to fill solution tanks, clean up spills, and wash equipment;
g. Be located in areas that have floors and walls constructed of material that is suitable to the chemicals being stored and that is capable of being washed; and
h. Be located in areas with floor surfaces that are smooth and impervious, slip-resistant, and well drained with three inches per ten feet minimum slope.

5.1.8. Service water supply.

a. The quality of service water supplied to a treatment facility shall be compatible with the purposes for which it is used. Generally, only potable water should be used. Any proposal to use non-potable plant service water shall be submitted to and approved by the department before construction. When potable water is not used, the hose bibs and all water lines carrying non-potable water shall be clearly labeled. No cross-connection between potable and non-potable water lines is allowed.
b. The amount of solution water used to operate the feeders in a plant should be kept to the minimum necessary. This is especially important in small water treatment facilities. When specifying chemical feeders, the amount of service water required to operate the feeder must be considered.
c. Service water supply shall be:
    1. Ample in supply and adequate in pressure;
    2. Provided with a totaling water meter to determine the amount of water used by the plant;
    3. Properly treated for hardness, when necessary; and
    4. Properly protected against backflow.

5.1.9. Storage of chemicals

a. Space shall be provided for:
    1. At least 30 days of chemical supply;
    2. Convenient and efficient handling and rotating of chemicals;
    3. Dry storage conditions; and
    4. A minimum storage volume of 1 1/2 truckloads where bulk purchase is by truck load lots.
b. Chemical storage areas shall be provided with the drains, sumps, finished water plumbing and the hose bibs and hoses necessary to clean up spills and to wash equipment.
c. Chemical storage areas shall have floors and walls constructed of material that is suitable to the chemicals being stored and that is capable of being cleaned.
d. Chemical storage areas shall be well lighted and heated if liquid chemicals are stored.
e. Floor surfaces shall be smooth and impervious, slip-resistant and well drained with three inches per ten feet minimum slope.
f. Vents from feeders, storage facilities, and equipment exhaust shall discharge to the outside atmosphere above grade and remote from air intakes.
g. Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals and not for alternates.

h. Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit.

5.1.10. Solution tanks.

a. All solution tanks shall be constructed of material compatible with the chemical contained.
b. All solution tanks shall be housed in a heated building or the tank and its chemical lines and transfer pumps protected from freezing.
c. All solution tanks shall be clearly labeled with the name of the chemical stored.
d. All solution tanks shall be tightly covered. Large solution storage tanks with access openings shall have such openings curbed and fitted with overhanging covers.
e. Bulk solution storage tanks shall be located and secondary containment provided so that chemicals from equipment failure, spillage, overflow, or accidental drainage shall not enter the water in conduits, treatment, storage basins, or waters of the state. Secondary containment volumes shall be able to hold the volume of the largest storage tank. Anchors shall be provided to prevent tank flotation in containment areas. Sumps and other methods for removing chemical spilled in the containment area shall be provided. For exterior containment areas manually operated sump pumps shall be provided to routinely remove precipitation from the containment area. Piping shall be designed to minimize or contain chemical spills in the event of pipe ruptures.
f. All solution tanks shall be located and protective curbing or containment provided so that chemicals shall not enter the water in conduits, treatment, or storage basins from equipment failure, spillage, or accidental drainage.
e. Buried solution tanks shall not be used.
f. All solution tanks shall be provided with means to easily measure the liquid level in the tank or otherwise determines the amount of solution in the tank;
g. Overflow pipes, when provided, shall be turned downward, with the end screened and have a free fall discharge that is directed to minimize splashing and damage to the surrounding area.
h. Bulk solution tanks shall have an overflow that is located where noticeable and a receiving basin or drain capable of receiving accidental spills or overflows.
j. All solution tanks shall have vents and overflows sized to handle the chemical and air flow occurring during tank filling and discharging.
k. All solution tanks should be vented individually. Tanks containing incompatible chemicals shall not be vented in common.
l. All solution tanks shall be vented to the outside of any structure, above grade and remote from air intakes with vents constructed of material compatible with the chemical being vented and screened to prevent insects from building nests that may plug the vent.
m. All solution tanks shall have chemical fill lines located for ease in connecting to supply trucks and filling. Side-filling bulk liquid trucks are the most common means, so driveways and fill line locations should be designed for this type of truck. Lengthy fill lines should be avoided;
n. All solution tanks shall have chemical fill lines clearly labeled with the name of the chemical contained in the tank they serve. One set of labels should be located

Deleted: i. Bulk liquid chemical-storage tanks must:
1. Be constructed of material compatible with the chemical being stored;
2. Have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, site tubes or a gauge rod extending above a reference point at the top of the tank, attached to a float, or other approved means may be used;
3. Have an overflow that is located where noticeable and a receiving basin or drain capable of receiving accidental spills or overflows;
4. Have an overflow line with a free fall discharge that is directed to minimize splashing and damage to the surrounding area;
5. Have chemical fill lines located for ease in connecting to supply trucks and filling. Side-filling bulk liquid trucks are the most common so driveways and fill line locations should be designed for this type of truck. Lengthy fill lines should be avoided;
6. Have chemical fill lines clearly labeled with the name of the chemical contained by the tank they serve. One set of labels should be located where the chemical supply trucks connect to the chemical fill lines;
7. Be vented to the outside above grade and remote from air intakes with vents constructed of material compatible with the chemical being vented and screened to prevent insects from building nests that may plug the vent;
8. Have vents and overflows sized to handle the chemical and air flow occurring during tank filling and discharging;
9. Have a valved drain, protected against backflow;
10. Be housed in a heated building or the tank and its chemical lines and transfer pumps otherwise protected from freezing; and
11. Be clearly labeled with the name of the chemical stored.
j. Full spill containment should be provided for all bulk storage tanks and shall be provided for some specific chemicals.

where the chemical supply trucks connect to the chemical fill lines.

o. Piping penetrating chemical solution tanks shall be tightly sealed to prevent the escape of chemical vapors.

p. All facilities shall have a means to assure continuity of chemical supply while servicing a liquid storage tank.

q. All solution tanks shall have means such as a valved drain, protected against backflow, to safely remove the chemical from each tank and allow access for servicing the tank.

r. Where appropriate, solution tanks shall have mixing systems that will adequately mix the solution to maintain chemical quality and effectiveness.

s. A means, which is consistent with the nature of the chemical solution, shall be provided in a solution tank to maintain a uniform strength of solution. Continuous agitation shall be provided to keep slurries in suspension.

t. Two solution tanks of adequate volume may be required for a chemical to assure continuity of supply in servicing a solution tank. When chemical solutions are mixed and fed in a batch process, solution tanks should be sized to minimize the filling frequency to no more than once per day.

u. Means shall be provided to measure the solution level in the tank.

v. Chemical solutions shall be kept covered. Large tanks with access openings shall have such openings curbed and fitted with tight overhanging covers.

w. Subsurface locations for solution tanks shall:
   1. Be free from sources of possible contamination; and
   2. Assure positive drainage for ground waters, accumulated water, chemical spills and overflows.

x. Overflow pipes, when provided, should:
   1. Be turned downward, with the end screened;
   2. Have a free fall discharge; and
   3. Be located where noticeable.

y. Acid storage tanks must be vented to the outside atmosphere, but not through vents in common with any other chemical.

z. Each tank should be provided with a valved drain, protected against backflow in accordance with paragraphs 5.2.5. and 6. of this document.

aa. Solution tanks shall be located and protective curbing provided so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water in conduits, treatment or storage basins.

5.1.11. Day tanks.

a. Day tanks shall be provided where bulk storage of liquid chemical is provided.

b. Day tanks shall meet all the requirements of paragraph 5.1.10. of this document.

c. Day tanks should hold no more than a 48-hour supply.

d. Day tanks shall be scale-mounted.

e. Hand pumps shall be provided for transfer of acids, caustic solutions or other hazardous chemicals from a carboy or drum into a day tank. For non-hazardous chemicals, a tip rack may be used to permit withdrawal into a bucket from a spigot. Where motor driven transfer pumps are provided, a liquid level limit switch and an overflow from the day tank must be provided. The overflow from the day tank

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must drain by gravity back into the bulk storage tank or to a receiving basin or drain capable of receiving accidental spills or overflows.

f. A means that is consistent with the nature of the chemical solution shall be provided to maintain uniform strength of solution in a day tank. Continuous agitation shall be provided to maintain chemical slurries in suspension.

g. Tanks shall be properly labeled to designate the chemical contained.

h. Motor driven transfer pumps from bulk storage tanks shall be constructed and specified to handle the specific chemical being pumped.

i. Motor driven transfer pumps from bulk storage tanks shall be sized so they can fill the day tank while chemical is fed at the maximum output of the chemical feeder(s) pulling from the day tank. Under these conditions, the transfer pump(s) should be capable of filling the day tank in ten minutes, but no more than an hour. Where more than 10 minutes is required to fill a day tank, a liquid level limit switch that automatically shuts off the transfer pumps shall be provided.

j. Motor driven transfer pumps from bulk storage tanks shall be provided with discharge and suction valves located to allow the pump to be removed for maintenance without draining chemical from the lines to the bulk or day tank.

k. Containment should be provided for day tanks. Complete containment shall be provided where solution tanks or day tanks are in locations where the contents could drain to the water being treated.

5.1.12. Chemical Feed lines.

a. All chemical feed lines should be as short as possible in length of run and should be straight.

b. Chemical feed lines should not be buried. When chemical feed lines are buried, they shall be constructed of pressure piping designed to be buried and installed in encasement conduits to allow fro removal, replacement and repair.

c. Injector/diffusers shall be used when pumping chemical solutions into pipes. The solution injector/diffuser must be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point. Retractable injectors shall have a safety line provided between the injector valve and the injector nozzle to prevent the injector nozzle from being completely withdrawn and to prevent blowout.

d. Chemical solution lines:
   1. Should feed by gravity, where possible;
   2. Shall be of durable, corrosion resistant material that is compatible with the specific chemical being fed;
   3. Shall be easily accessible throughout the entire length;
   4 Shall be protected against freezing;
   5. Shall be adequately supported to prevent excessive movement and low areas where chemical will accumulate; and
   6. Shall be constructed to minimize plugging and to facilitate cleaning.

e. Chemical feed lines should slope upward from the chemical source to the feeder when conveying gases.

f. Chemical feed lines shall be designed consistent with scale-forming or solids-depositing properties of the water, chemical, solution, or mixture conveyed and shall be compatible with the chemical being fed.

g. Chemical feed lines should be color-coded, placarded, or otherwise clearly labeled with the name of the chemical contained. (See section 2.14. of this document).

h. Chemical feed lines shall be located so that plant operators do not have to routinely climb over them to get to other operating areas in the plant even if stiles or stairways are built over feed lines.

i. Chemical feed lines shall be located so that operators do not have to routinely walk under lines carrying strong corrosive, caustic or acid solutions.

5.1.13. Pumping of Chemicals.

When feeding of chemicals by gravity cannot be attained, pumping of chemicals to the different points of application may be considered. The chemical feed pumping system shall provide:

a. Standby pumping or eductor equipment;

b. Spare chemical feed line for each chemical;

c. Minimum velocity of 4 feet per second through chemical feed lines;

d. For pigging chemical feed lines and baskets for catching pigs;

e. Water for flushing the chemical feed lines. The waterline must be protected from back-siphonage;

f. Discharge and suction valves located to allow each pump or eductor to be removed for maintenance or a means to safely drain the lines prior to disconnection for repairs;

g. Pumps and eductors constructed from material that is compatible with the specific chemical being pumped and that are easy to access, disassemble, and maintain;

h. Pumps that are located so that they are not tripping or fall hazards and so that they or their motors are not subject to damage by chemical spilled during routine loading and operation of solution tanks or feeders; and

5.1.14. Handling.

Deleted: i. Encasement conduits for underground feed lines for easy removal and maintenance.¶

a. Carts, elevators, and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.

b. Provisions shall be made for disposing of empty bags, drums, or barrels by an approved procedure that will minimize exposure to dusts.

c. Provision shall be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize dust. Control should be provided by use of:

   1. Vacuum pneumatic equipment or closed conveyor or elevator systems;
   2. Facilities for emptying shipping containers in special enclosures; or
   3. Exhaust fans and dust filters that put the hoppers or bins under negative pressure.

d. Provision shall be made for measuring quantities of chemicals used to prepare feed solutions.

5.2. Chemicals.

5.2.1 Shipping containers.

Chemical shipping containers shall be fully labeled to include chemical name, purity, and concentration and supplier names and addresses.

5.2.2 Assay.

Provisions should be required for assay of bulk chemicals delivered to assure the chemicals meet industry standards and/or design specifications.

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5.2.3 Specifications

Chemicals shall meet the appropriate ANSI/AWWA standards and/or ANSI/NSF Standard 60 and/or be certified as being food grade.

5.3. Operator Safety.

5.3.1. Ventilation.

a. Provisions shall be made for ventilation of all chemical feed and/or storage areas for dust and vapor control.

b. Special provisions shall be made for ventilation of chlorine, chlorine dioxide, anhydrous ammonia, ammonium hydroxide, powdered activated carbon, sodium hypochlorite generation and ozone generation, feed and storage rooms.

5.3.2. Respiratory protection equipment.

a. Respiratory protection equipment meeting the requirements of NIOSH shall be available for each chemical dust, vapor, or gas that may be encountered at a treatment plant. This respiratory protection equipment shall be stored at a convenient location, but not inside any room where the particular chemical is used or stored.

b. Self contained breathing apparatus units shall use compressed air, have at least a 30 minute capacity, have full face masks, and be compatible with units used by the fire department responsible for the plant.

5.4. Specific Chemicals.

Chemical storage handling and feeding facilities for the chemicals specified here shall meet all of the appropriate general requirements of this document and the chemical-specific requirements specified in this chapter.

5.4.1. Chlorine gas.

Contact between chlorine and many combustible substances such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, sulfur, reducing agents, and finely divided metals may cause fires and explosions. Contact between chlorine and arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomonosilane, potassium, propylene, and silicon should be avoided. Chlorine reacts with moisture, steam, and water to create hydrochloric and hypochlorous acids. Therefore chlorine rooms shall be kept dry. Design of treatment facilities using gas chlorine must prevent the contact of the gas with incompatible substances and conditions.

Exposure to chlorine gas has caused death, lung congestion, and pulmonary edema, pneumonia, pleurisy, and bronchitis. Chronic exposure to low levels of chlorine gas or vapors from chlorine solutions can result in a dermatitis known as chloracne, tooth enamel corrosion, coughing, severe chest pain, sore throat, hemoptysis, and increased susceptibility to tuberculosis. Design of chlorine facilities shall include applicable safety measures and equipment to protect the facility operators.

a. Chlorine gas feed and storage shall be enclosed and separated from other operating areas. The chlorine room or building shall be:
    1. Constructed of fire and corrosion resistant material;
    2. Provided with a shatter resistant inspection window installed in an interior wall for chlorine rooms;
    3. Orientated so that the feeder settings and scale readings can be easily read from the inspection window and eliminate the need to frequently enter the room or building;
    4. Constructed in such a manner that all openings in a chlorine building or between the chlorine room and the remainder of the plant are sealed. These seals must be capable of withstanding the pressures expected from expanding chlorine gas. Areas sealed shall include, but not be limited to, electrical conduit, switches, lights and receptacles, ducts, wall, and ceiling and floor joints. Floor drains are not recommended; however, where installed, they shall be plugged or sealed. All holes through the walls, ceiling and floor shall be sealed around where pipes conduits, wires, brackets, fixtures, etc., pass. All chlorine building or room doors shall be designed and fitted to contain chlorine gas leaks inside the room or building;
    5. Provided with doors equipped with panic bars assuring ready means of exit and opening only to the building exterior;
    6. Provided with doors that lock to prevent unauthorized access but do not need a key to exit the locked room using the panic bars**;**
    7. Well lighted with lights that are sealed so that they will continue working during a chlorine leak;
    8. Sized to allow the safe maneuvering of gas cylinders using hand trucks or electric hoists; and
    9. If free-standing, located down grade from the water treatment plant.
b. Full and empty cylinders of chlorine gas shall be:
    1. Housed in a completely enclosed chlorine storage building or room and protected from exposure to weather, extreme temperature changes and physical damage;
    2. Restrained in position to prevent upset or rolling, and shall not be stacked;
    3. Stored separate from incompatible material; and
    4. Stored in areas not in direct sunlight or exposed to excessive heat.
c. Where chlorine gas is used, the building or room shall be constructed to provide the

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Deleted: ammonia, ammonium hydroxide, paint thinner, solvent and petroleum product storage following:

1. Each room or building shall have a ventilating fan or fans with a capacity that provides one complete air change per minute when the room is occupied. The fans shall be constructed of chemical resistant materials and have chemical proof motors. Squirrel cage type fans located outside the chlorine room(s) may be approved if their fan housings and ducting are airtight and made of chlorine and corrosion resistant material;
2. The ventilating fan(s) shall take suction near the floor as far as practical from the door and air inlet, with the point of discharge located remote from the entrance door to the chlorine room and so that exhausted chlorine gas will not enter any other parts of the water plant or other buildings**,** rooms or structures. Wall fans located in or beside the entrance doors to chlorine feed or storage room shall not be allowed;
3. Air inlets shall be from the outside the building and be through louvers near the ceiling. These inlet louvers shall seal tightly. Motor operated louvers shall be provided with chlorine and corrosion resistant motor controls and electric connections;
4. Separate switches for fans and lights shall be outside of the room and beside the entrance door and the interior inspection window. These switches shall be clearly labeled as to what they operate. A signal light indicating fan operation should be provided;
5. Vents from feeders and storage containers shall discharge to the outside atmosphere, above grade and be screened to prevent insects from nesting in and plugging the vents; and
6. Where located near residential or developed areas and deemed necessary by the department, provision shall be made to chemically neutralize chlorine gas before discharge from the water treatment plant building into the environment. Such equipment shall be designed as part of the chlorine gas storage and feed areas to automatically engage in the event of any measured chlorine release. The equipment shall be sized to treat the entire contents of the largest storage container on site.

d. Heating equipment for chlorinator rooms shall be capable of maintaining a minimum temperature of 60°F, and the cylinders shall be protected from direct or excessive heat. Cylinders and gas lines should be maintained at the same temperature as the feed equipment. Equipment used to heat a chlorine storage or feed area shall be located a safe distance from, and shall not blow directly onto chlorine cylinders. Heating or air conditioning equipment provided shall be separate from central heating and air conditioning systems to prevent chlorine gas from entering the central system. Central heating or cooling ducts shall not terminate in or pass through a chlorine room.

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e. Pressure chlorine feed lines shall not carry chlorine gas beyond the chlorinator room. Chlorine gas feed systems that are under a vacuum from the gas cylinder valve out are preferred**.**

f. Sufficient chlorine gas manifolds, cylinder valves, piping and other equipment shall be provided to connect enough chlorine storage containers to a feeder or feeders so as to not exceed the dependable continuous discharge rate of any chlorine gas container. Circulating fans shall not be used to prevent frosting of containers or freezing of feed lines or to increase discharge rates. The normal dependable continuous discharge rate from a 150-lb or 100-lb chlorine gas cylinder is 1¾ pounds per hour at 70 °F and a 35 psi backpressure.

g. Chlorine gas leak detection and control.
   1. A bottle of ammonium hydroxide, 56 percent ammonia solution, shall be available for chlorine leak detection.
   2. Where ton or larger containers are used, at least one atmospheric chlorine gas detector shall be provided in each chlorine storage and feed room. Atmospheric chlorine-gas detectors shall be continuous leak-detection equipment and shall be provided with both an audible alarm and a warning light. Continuous leak-detection equipment should be provided for systems using 150-lb or smaller cylinders.
   3. Where ton containers are used, a leak repair kit approved by the Chlorine Institute shall be provided.
   4. Valves should be provided that will automatically shut off all active chlorine-gas cylinders during a leak.
      1. These valves shall be mounted on the chlorine-gas cylinder valves and shall be capable of rapidly shutting off a cylinder even during a power failure.
      2. The valves and all other parts of the automatic system shall be constructed of or encased in chlorine compatible and corrosion resistant material
      3. Operation of the valves shall be controlled by a signal from an atmospheric chlorine gas detector or control room.
      4. A manual shut-off switch shall be provided that also acts as a test switch to provide a full cycle test of the valve actuator.
      5. Audible alarms and warning lights shall be provided indicating when a gas leak and valve shut down has occurred.
      6. Running lights shall be provided to indicate whether a valve is closed or open.

h. Chlorination equipment.
   1. Type. Solution-feed gas chlorinators or hypochlorite feeders of the positive displacement type must be provided for feeding the chlorine compounds, and ozonation equipment as specified for feeding ozone.
   2. Capacity. The chlorinator capacity shall be such that a free chlorine residual of at least 2 milligrams per liter can be maintained in the water after the required chlorine contact time even when maximum flow rate coincides with anticipated maximum chlorine demand. The equipment shall be of such design that it will operate accurately over the desired feeding range.
   3. Standby equipment. Where chlorination is required for disinfection or other essential processes, standby equipment of sufficient capacity shall be available to replace the largest unit. In addition, spare parts shall be made available to replace parts subject to wear and breakage or a required replacement schedule.
   4. Automatic switchover. Automatic switchover of chlorine cylinders should be

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provided, where necessary, to assure continuous disinfection.

5. Automatic proportioning. Automatic proportioning chlorinators will be required where the rate of flow or chlorine demand is not reasonably constant.
6. Eductor. Each eductor must be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum injector water flow, the total discharge back pressure, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure and vacuum at the inlet and outlet of each eductor should be provided.
7. Injector/diffuser. Injectors shall be used when feeding chlorine into pipes. The chlorine solution injector/diffuser must be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point. Retractable injectors shall have a safety line provided between the injector valve and the injector nozzle to prevent the injector nozzle from being completely withdrawn and to prevent blowout.
8. Where chlorine is fed into a basin, the exit point of the chlorine feed shall be at least four feet below the water surface and shall be fed through a diffuser. This is to prevent off-gassing of chlorine and chlorine vapors as well as promote mixing.

i. Chlorinator piping.

1. Cross connection protection. The chlorinator water supply piping shall be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, pre and post chlorination systems must be independent to prevent possible siphoning of partially treated water into the clearwell. The water supply to each eductor shall have a separate shut-off valve. No master shut-off valve will be allowed.
2. Pipe material. The pipes carrying elemental liquid or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.

5.4.2. Sodium Hypochlorite.

Strong sodium hypochlorite solutions are highly alkaline and powerful oxidizing agents that rapidly produce burns when in contact with the skin.. Inhalation of mist or fumes can cause bronchial irritation, cough, difficult breathing, inflammation of the mouth, nausea, and in sever exposures, pulmonary edema.

When mixed with ammonia or ammonium compounds, explosive products may be formed. Sodium hypochlorite reacts vigorously with amines, ammonium salts, reducing agents, methanol, acids, and most organics and will liberate chlorine gas. Design of sodium hypochlorite storage and feed facilities shall assure separation from incompatible chemicals.

For strong sodium hypochlorite solutions (greater than 5.25%), problems that shall be considered during design are plugging of discharge piping due to scale formation, plugging of suction lines and pumps due to solution degradation and impurities in the solution, and the formation of gas (chlorine and oxygen) in the pumps and piping system.

a. Storage

1. The sizing of storage tanks and the selection of the strength of the solution must be balanced with the fact that the solution degrades and loses strength over time. One of the compounds produced as sodium hypochlorite solutions degrade is sodium chlorate. While not presently regulated as a contaminant, design should include minimizing the amount of chlorates introduced into the water. A minimum of 30 days supply shall be maintained to assure continues disinfection, but the maximum storage life should be 60 to 90 days. More dilute sodium hypochlorite solutions degrade less quickly.
2 Due to off-gassing, all storage containers and tanks shall be tightly sealed and properly vented out of all structures to the atmosphere.
3. Because the rate of degradation increases with heat and sunlight, tanks shall be made of opaque polyethylene or coated fiberglass and should be housed to prevent extreme temperatures (less than 32 ºF or more than 80 ºF) and degradation of the hypochlorite solution.
4. All sodium hypochlorite tanks, piping, pumps, fittings, etc. shall be compatible with the chemical. Metal shall not be used anywhere in a hypochlorite system as corrosion will occur and the metals will permeate the hypochlorite solution. The presence of metals will contribute to the decomposition of the hypochlorite solutions and the development of chlorates. As much piping as possible should be rigid PVC or CPVC schedule 90. Nylon fittings shall not be used for hypochlorite.

b. Solution pumps

1. For sodium hypochlorite piping PVC diaphragm valves are preferred but PVC lines valves and PVC plug valves are acceptable. To reduce potential gas build-up or rupture, consideration should be given to using vented ball valves.
2. A strainer shall be installed in each suction line or header to capture any impurities in the hypochlorite solution. Strainers shall be located and valved so that they are easily accessible for frequent cleaning. Suction should not be drawn off the bottom of a container.
3. Pump(s) should be located as close to the supply container as possible to keep suction lines short. Avoid piping metering pumps with suction lift as this will increase the tendency to outgas.
4. Gas bleed-off equipment shall be installed on the discharge piping as

close to the pump as possible and at a high point.

5. Appropriate safety equipment shall be provided to protect operators consisting of, but not limited to gloves, face masks or eye goggles, rubber aprons or suits and rubber boots.
6. Injectors shall be made removable for regular cleaning where hard water is to be treated. Retractable injectors shall have a safety line provided between the injector valve and the injector nozzle to prevent the injector nozzle from being completely withdrawn and to prevent blowout. Standby injectors and Y-strainers are recommended.

5.4.2. Acids.

a. Acids shall be kept in closed acid-resistant shipping containers or storage units.
b. Acids shall not be handled in open vessels, but shall be pumped in undiluted form from original containers through a suitable piping to the point of treatment or to a tightly sealed, vented and covered day tank.
c. To reduce the hazard to the water plant, acids shall not be diluted. Instead, the metering pumps specified shall permit the use of undiluted acid for installations of any size.
d. With the exception of Fluorosilicic acid, acids shall not be stored in the same area as sodium chlorite and sodium chlorate solutions or in chlorine feed or storage rooms or in any area that may be affected by a chlorine gas leak or vapors from chlorine solutions or compounds.

5.4.3. Chlorine Dioxide.

Chlorine dioxide is a very unstable material even at room temperatures. Airborne concentrations greater than 10 percent will explode on impact when exposed to sparks or sunlight, or when heated rapidly to 100 ºC. Contact with the following materials may cause fires and explosions: carbon monoxide, dust, fluoroamines, fluoride, hydrocarbons (e.g., butadiene, ethane, ethylene, methane, and propane), hydrogen, mercury, phosphorus, sulfur, platinum, or potassium hydroxide. Chlorine dioxide reacts with water or steam to form toxic and corrosive fumes of hydrochloric acid. Consequently, chlorine dioxide is generated on site and fed as dilute solutions. Chlorine dioxide is generated by mixing precisely measured amounts of chlorine, sodium chlorite or chlorate and sometimes hydrochloric or sulphuric acid. Storage of chlorine dioxide solution is not recommended.

Acute exposure to chlorine dioxide causes irritation of the eyes, nose, and throat; coughing, wheezing, shortness of breath, bronchitis, pulmonary edema, headache, and vomiting. Chronic exposure to chlorine dioxide may cause chronic bronchitis and emphysema. Chlorine dioxide generation facilities must be housed in the same manner as chlorine gas facilities and the same type of operator safety equipment provided.

a. Sodium chlorite and sodium chlorate solutions and acids used to generate chlorine dioxide shall not be stored together or in chlorine feed or storage rooms or in any area that may be affected by a chlorine gas leak or by vapors from chlorine solutions or compounds.

b. Federal and state rules set plant and distribution system monitoring requirements for systems feeding chlorine dioxide. Chlorites are a regulated byproduct of the chlorine dioxide generation and feeding process that must be routinely monitored. Thus, the necessary approved analyses equipment, monitoring equipment, and laboratory facilities shall be provided to test for chlorine dioxide and chlorites.

c. Sodium Chlorite and Sodium Chlorate Storage.

1. The department, before the preparation of final plans and specifications, shall approve proposals for the storage and use of sodium chlorite and chlorate.
2. Provision shall be made for proper storage and handling of sodium chlorite and chlorate to eliminate any danger of fire or explosion associated with their powerful oxidizing nature. Dry sodium chlorite and chlorate are a fire and explosion hazard and their use in this form is not recommended.
3. Sodium chlorite or chlorate solutions shall be stored by themselves in a cool, dry, fireproof, separate room. Preferably, they should be stored in an outside building detached from the water treatment facility.
4. Sodium chlorite or chlorate solutions shall be stored away from organic materials because many materials will catch fire and burn violently when in contact with sodium chlorite or chlorate.
5. Storage shall be away from combustibles and acids.
6. The storage structures shall be constructed of noncombustible materials.
7. If the storage structure must be located in an area where a fire may occur, water shall be available to keep the sodium chlorite area cool enough to prevent heat-induced explosive decomposition of the chlorite.
8. The storage structure shall be provided with a separate, non-combustible, corrosion-resistant ventilation system designed for mist or fumes.
9. Full spill containment shall be provided. Furthermore, storage facilities shall not be located over plant treatment basins, pumping wells, transfer wells, or clearwells.

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d. Sodium Chlorite and Sodium Chlorate Handling

1. The design shall provide the drains, sumps, finished water plumbing, hose bibs and hoses necessary to clean up spills and to wash equipment.
2. An emergency plan of operation should be developed for the clean up of any spillage.
3. Storage drums must be thoroughly flushed before recycling or disposal.
4. Protective safety equipment for the operators shall be provided that includes, but may not be limited to, chemical safety goggles, butyl rubber or neoprene gloves, self-contained breathing apparatus and waterproof outer clothing.

e. Sodium Chlorite and Sodium Chlorate Feeders.

1. Positive displacement feeders shall be provided for feeding the acids and sodium chlorite and chlorate solutions.
2. Methods for accurately metering or weighing the sodium chlorite and chlorate solutions shall be provided. Graduated measuring chambers should be built into the feeder piping to allow the feeder output to be routinely checked.

3. Tubing for conveying sodium chlorite or chlorine dioxide solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.
4. Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.
5. Check valves shall be provided to prevent the backflow of chlorine into sodium chlorite or chlorate lines.
6. Storage tanks inside buildings, day tanks and unsealed carboys or barrels shall be vented to the outside with a vent approved by the department.
7. To reduce the hazard to the water plant operators, sodium chlorite and chlorate solutions and the required acids shall not be diluted. Instead, the metering pumps specified shall permit the use of undiluted solutions for installations of any size.

5.4.4. Chloramines.

a. Anhydrous ammonia.
   1. Anhydrous ammonia storage and handling facilities shall be designed to meet OSHA Standard 1910.111.
   2. With rising temperature, ammonia expands rapidly, increasing the internal pressure in vessels and pipes, etc. This shall be considered in the design and operation of ammonia systems
   3. Anhydrous ammonia feeding facilities shall be located in a separate enclosed room in the same manner as chlorine gas facilities, and the same type of operator safety equipment provided. See section 5.4.1. In addition, only explosion-proof electric fixtures shall be used in the room.
   4. Anhydrous ammonia contact with chlorine or fluorine can create explosive compounds. Therefore, feeding and storage facility design shall consider methods of preventing ammonia or chlorine leaks from coming into contact with either chemical. Furthermore, fluoride-feeding facilities shall not be located in ammonia feeding or storage rooms.

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b. Ammonia Solutions.
Ammonia solutions such as aqueous ammonia, aqua ammonia, ammonia TS and ammonium hydroxide are corrosive alkaline solutions that cause burns to any area of contact and are harmful if swallowed, inhaled or absorbed through skin.

   1. Storage.
      a. Ammonia solutions shall be kept in tightly closed containers stored in a separate cool, dry, ventilated room and kept from all forms of chlorine, strong acids, most common metals, strong oxidizing agents, aluminum, copper, brass, bronze, chlorite or chlorate solutions, and other incompatible chemicals.
      b. Ammonia solutions shall be protected from direct sunlight.
      c. The storage room shall be provided with a separate, corrosion-resistant ventilation system to capture mist or fumes and vent them to the outside.
      d. Ammonia solution containers may be hazardous when empty since they retain product residues. Therefore, all warnings and precautions

listed for the product should be observed for empty containers.

2. Ammonia Solution Handling.
   a. Ammonia solutions are very toxic to aquatic life and spills may not be drained into some sanitary sewer systems. Therefore, full spill containment shall be provided.
   b. Absorbent pads and the drains, sumps, finished water plumbing, hose bibs, and hoses necessary to clean up spills and to wash equipment shall be provided.
   c. An emergency plan of operation should be developed for the clean up of any spillage.
   d. Provide protective safety equipment for water plant personnel that include, but are not limited to chemical safety goggles, butyl rubber or neoprene gloves, self-contained breathing apparatus and water proof outer clothing.
   e. To reduce the hazard to the water plant personnel, ammonia solutions shall not be diluted. Instead, solution with the correct strength for the amount fed shall be purchased, or the metering pump specified shall permit the use of undiluted solution for water plants of any size.

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3. Ammonia Solution Feeders.
   a. Positive displacement feeders shall be provided for feeding the ammonia solutions.
   b. Methods for accurately metering or weighing the ammonia solutions shall be provided. Graduated measuring chambers should be built into the feeder piping to allow the feeder output to be routinely checked.
   c. Tubing for conveying ammonia solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.
   d. Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.
   e. Storage tanks and unsealed carboys or barrels shall be vented to the outside with a vent approved by the department.

c. Ammonium Sulfate Solutions

Ammonium sulfate causes irritation to skin, eyes, and respiratory tract and may be harmful if swallowed, but does not present the safety issues of other ammonia solutions. It can be treated as an ordinary chemical solution.

5.4.5. Carbon dioxide

Carbon dioxide gas is a colorless odorless gas that is an asphyxiant. Since it is heavier than air, it can build up in low areas without warning. If the concentration of carbon dioxide reaches 10% or more, suffocation can occur rapidly. Inhalation of concentrations between 2 and 10% can cause nausea, dizziness, headache, mental confusion, increased blood pressure and respiratory rate.

a. Recarbonation basin design shall provide:
   1. A minimum detention time of twenty minutes,
   2. Two compartments, each with a depth of eight feet, as follows:

i. A mixing compartment having a detention time of at least three minutes; and
ii. A reaction compartment.

b. If a carbon dioxide solution is added and rapid mixing is provided, total detention time and basin depths may be reduced. However, supporting data for the proposed reductions must be included as a part of the pre-design submittals.
c. Plants generating carbon dioxide from combustion shall have open top, recarbonation tanks in order to dissipate carbon monoxide and carbon dioxide. Special considerations shall be given to building ventilation when open recarbonation tanks are housed in a building.
d. Where liquid carbon dioxide is used, adequate precautions must be taken to prevent carbon dioxide from entering the plant from the feed lines or recarbonation process. Since liquid carbon dioxide is a cryogenic and a compressed gas, the recommendations of the Compressed Gas Association, Inc. shall be followed when specifying storage and feeding facilities.
e. Provisions shall be made for draining recarbonation basins and removing residuals.

5.4.6. Phosphates.

a. Stock phosphate solution must be kept covered and disinfected by carrying approximately ten milligrams per liter free chlorine residual in the stock solution. The total phosphate applied shall not exceed 10 milligrams per liter as orthophosphate. Possible adverse affects on corrosion must be addressed when phosphate addition is proposed for iron sequestering.
b. Phosphates can act as a nutrient for biological growth in water distribution systems. Therefore, disinfection equipment shall be provided that is sufficient to maintain disinfectant residuals throughout the distribution system at levels necessary to control biological growths. Continuous disinfection of the water with free available chlorine must be practiced. Heterotrophic bacteria studies should be done routinely to ensure that biological growths are controlled through out the distribution system.
c. Laboratory testing equipment shall be provided to routinely test the water for total phosphate and orthophosphate.
d. Before feeding a phosphate compound, the purpose for feeding the compound must be considered. Sequestration of iron, manganese, or calcium requires polyphosphates with limited orthophosphate concentrations. Inhibition of corrosion to protect water mains or to control lead and copper concentrations requires mainly orthophosphates and generally zinc-orthophosphate. Polyphosphates have been shown to increase lead and copper concentrations under certain circumstances. Submittals to the department shall state the purpose for feeding the phosphate compound and provide justification that the chosen phosphate compound works for the intended purpose.
e. PH and alkalinity significantly impact the effectiveness of different phosphate treatments. Submittals to the department shall include the results of studies done in waters with similar pH and alkalinities proving that the proposed treatment works for the intended purpose.

5.4.7. Permanganate.

1. General information

Potassium permanganate ($KMnO_4$) and sodium permanganate ($NaMnO_4$) are strong oxidants and are used primarily to control taste and odors, remove color, control biological growth in treatment plants, reduce disinfectant bi-products and remove iron and manganese. Permanganate is usually added ahead of chlorine and activated carbon for taste and odor control, and after chlorine for iron and manganese oxidation. In all cases, potassium permanganate is added prior to filtration.

As an oxidant, sodium permanganate will accelerate the burning of combustible materials such as wood and paper products and most clothing. For this reason, strong solutions of sodium permanganate shall not be stored or used on wooden floors, or on wood pallets; only concrete floors are recommended. Both permanganate types shall not be stored in proximity to acids, peroxides, sulfites, oxalates and all other oxidizable inorganic chemicals, or with or in proximity to organic material such as carbon, wood, paper or cloth.

2. Safety equipment

Safety equipment shall be provided for the operators that includes, but should not be limited to, face shields and or goggles, rubber or plastic gloves, and rubber or plastic apron. Where potassium permanganate is used, appropriate NIOSH-MSHA dust or mist respirators are recommended.

3. Permanganate addition
   a. The feed rate shall be based on jar testing
   b. A jar tester should be available in the lab for determining proper dosages.
   c. When permanganate is added at a sedimentation basin, a sample point near the end should be provided to test for presence of pink color which should disappear before filtration.
   d. Chemical feed equipment and methods. Permanganate solution feed equipment shall meet the following requirements:
      1. The permanganate solution feed system shall be installed so that it cannot operate unless water is being produced (interlocked). For example, the metering pump shall be wired electrically in series with the main well pump or the service pump, and it shall be made physically impossible to plug the permanganate solution metering pump into any continuously active ("hot") electrical outlet.
      2. A secondary flow-based control device (e.g., a flow switch or a pressure switch) shall be provided as back-up protection.
      3. Permanganate should not be fed by gravity flow.
      4. Flow paced systems are required where the rate of raw water can vary more than 20%. An example is the use of multiple wells to supply a treatment plant where the number of wells operating at any one time may vary.

5. Two diaphragm-type anti-siphon devices shall be provided. The anti-siphon devices should have a diaphragm that is spring-loaded in the closed position and should be selected to provide the backpressure required by the pump manufacturer in the permanganate solution feed line when a metering pump is used. For diaphragm and centrifugal solution pumps, one device shall be located at the solution injection point and one device shall be located at the metering pump head on the discharge side. For peristaltic solution pumps and eductors, one anti-siphon device shall be located at injection point.
6. Permanganate solution shall be fed through injectors or diffusers that are equipped with anti-siphon devices.
7. Permanganate solution shall not be injected in a point of negative pressure.
8. Operation of a permanganate system without a functional anti-siphon device can lead to overfeed. Therefore, maintenance manuals, tools and repair parts shall be provided so that all anti-siphon devices can be dismantled and visually inspected at least once a year. Manufacturer's recommended schedules of repairs and replacements shall be provided. Equipment for semiannual vacuum testing of all anti-siphon devices should be provided.
9. Permanganate solution metering pumps should be located on a shelf not more than 4 feet (1.2m) higher than the lowest normal level of liquid in the carboy, day tank, or solution container. A flooded suction line is not recommended.
10. For greatest accuracy, metering pumps should be sized to feed permanganate solution near the midpoint of their range. Oversized metering pumps shall not be used because serious overfeeds (exceeding 4 mg/L) can occur if they are set too high.
11. The permanganate solution feed line(s) should be either color coded, when practical, or clearly identified by some other means. Color coding helps prevent possible errors when taking samples or performing maintenance.
12. Where solutions are made of potassium permanganate,
    a. A source of heated water should be available for dissolving potassium permanganate;
    b. The dilution water pipe shall end at least two pipe diameters above the highest water level in the solution tank, or an adequate backflow prevention device must be provided;
    c. All hose connections within reach of the permanganate solution feed equipment should be provided with a hose-bib vacuum breaker; and
    d. Mechanical mixer(s) shall be provided.

4. Solution tanks – day tanks
   a. Spill containment shall be provided for solution tanks. The containment should be sufficient to hold the release of one full container. Complete

containment shall be provided where solution tanks or day tanks are in location where the contents could drain to the water being treated or the raw water intake. Bulk storage facilities shall not be located over plant treatment basins, pumping well, transfer wells or clear-wells.

b. Methods for accurately metering or weighting the solution shall be provided.

5. Permanganate storage

a. Permanganate, both sodium and potassium, must be stored in accordance with the latest NFPA (National Fire Protection Association) requirements for Class II Oxidizers. The product should be stored in a cool, dry area in closed containers, away from heat and organic compounds to avoid potential explosions. Product should be stored above 50ºF. Concrete floors are preferred, wooden decks are not permitted.

b. The recommended response for a sodium permanganate spill is dilution with sufficient quantities of water. Therefore, hose bibs and water supply piping to supply water for clean up of spills shall be provided in both the chemical feed and storage areas. The number of hose bibs and their location depend upon the size of the areas served.

6. Spill Response

The design of the facility shall take into account the recommended practices for a sodium or potassium permanganate spill.

5.4.8. Powdered activated carbon.

a. Powdered activated carbon feed and storage facilities.
1. Powdered activated carbon shall be handled as a potentially combustible material.
2. Powdered activated carbon shall be stored in a building or compartment as nearly fireproof as possible.
3. A separate room shall be provided for carbon feed installations and other chemicals should not be stored in the same compartment.
4. Carbon feeder rooms shall be equipped with explosion-proof electrical outlets, lights and motors.
5. If possible, the feeder drive controls should be located outside the carbon room.
6. The carbon feed room should be large enough to house the carbon feeder and to store all of the powdered carbon present at the plan safely. Thus, the door to the carbon feed and storage room must be large enough to accommodate a loaded pallet of carbon.
7. Access to the carbon room should be from outside the plant to keep carbon from being tracked throughout the water plant.

b. Powdered activated carbon feeding.
1. Powdered activated carbon should be added as early as possible in the treatment process to provide maximum contact time.
2. Flexibility to allow the addition of carbon at several points is required.
3. Powdered activated carbon should not be applied near the point of chlorine

application.
4. The effectiveness of powdered activated carbon depends upon the carbon particles physically contacting the chemicals to be adsorbed. Therefore, flash mixing shall be provided to ensure an even dispersion of the carbon in the water.
5. The carbon can be added as pre-mixed slurry or by a dry-feed machine as long as the carbon is properly wetted. However, solution pipe plugging is a constant problem when pumping carbon slurries. Carbon feed design must consider ways to mediate this problem by using wetting cones and eductors, dual headed slurry pumps, etc**.**
6. Continuous agitation or suspension equipment is necessary to keep the carbon from depositing in the slurry storage tank.
7. Provision shall be made for adequate dust control by providing exhaust fans and dust filters**.**
8. Provision shall be made for adding from 0.1 milligram per liter to at least 50 milligrams per liter at the maximum design flow of the treatment facilities.

c. Powdered activated carbon handling.
1. Operators shall be provided with respiratory protection that meets OSHA regulation 29 CFR 1910.134 for coal dust. More information on the selection and use of respirators can be obtained from the latest issue of NIOSH Respirator Decision Logic.
2. Additional personal protective equipment to protect skin and eyes should be provided for dry feeder operations and shall be provided for operators that batch make carbon slurries.

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5.4.9. Fluoridation

Commercial sodium fluoride, sodium fluorosilicate and fluorosilicic acid shall conform to the appropriate American Water Works Association (AWWA) standards (B-701, B-702, and B-703) to ensure that the drinking water will be safe and potable. The department must approve other fluoride compounds that may be available. The department must approve the proposed method of fluoride application before preparation of final plans and specifications.

a. Fluoride compound storage. Fluoride chemicals should be isolated from other chemicals to prevent contamination. Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Adequate ventilation in storage area is necessary. Bags, fiber drums, and steel drums should be stored on pallets. Carboys, day tanks, or inside bulk storage tanks containing fluorosilicic acid must be completely sealed and vented to the atmosphere at a point outside any building. Bulk storage tanks for fluorosilicic acid must be provided with secondary containment and shall not be located over plant treatment basins, pumping wells, transfer wells or clearwells. Unsealed storage units for hydrofluosilicic acid shall be vented to the atmosphere at a point outside any building.

b. Chemical feed equipment and methods. Fluoride feed equipment shall meet the following requirements:

1. The fluoride feed system must be installed so that it cannot operate unless water is being produced (interlocked). For example, the metering pump must be wired electrically in series with the main well pump or the service pump. If a gravity flow situation exits, a flow switch shall be installed.
2. When the fluoridation system is connected electrically to a well or service pump, it must be made physically impossible to plug the fluoride metering pump into any continuously active ("hot") electrical outlet. The pump shall be plugged only into the circuit containing the interlock protection.
3. A secondary flow-based control device (e.g., a flow switch or a pressure switch) should be provided as back-up protection.
4. The fluoride injection point should be located where all the water to be treated passes. However, fluoride should not be injected at sites where substantial losses of fluoride can occur. Fluoride compounds shall not be added before lime-soda softening or ion exchange softening.
5. The fluoride injection point in a water line should be located in the lower one third of the pipe, and the end of the injection line should extend into the pipe approximately one-third of the diameter of the pipe.
6. A corporation-stop valve should be used at the fluoride injection point when injecting fluoride under pressure. To protect water plant operators, a safety chain shall be installed in the assembly at the fluoride injection point if a corporation stop valve assembly is used.
7. Two diaphragm-type anti-siphon devices must be installed in the fluoride feed line when a metering pump is used. These anti-siphon devices should have a diaphragm that is spring-loaded in the closed position. One device should be located at the fluoride injection point and one device shall be located at the metering pump head on the discharge side. Metering pump anti-siphon devices should be selected to provide the backpressure required by the pump manufacturer.
8. Operation of a fluoridation system without a functional anti-siphon device can lead to overfeed that exceeds 4 mg/L. Therefore, maintenance manuals, tools and repair parts must be provided to the system operators so that all anti-siphon devices can be dismantled and visually inspected at least once a year. Schedules of repairs or replacements should be based on the manufacture's recommendations. Equipment for semiannual vacuum testing of all anti-siphon devices should be provided.
9. Fluoride metering pumps should be located on a shelf not more than 4 feet (1.2 m) higher than the lowest normal level of liquid in the carboy, day tank, or solution container. A flooded suction line is not recommended in water fluoridation.
10. For greatest accuracy, metering pumps should be sized to feed fluoride near the midpoint of their range. Pumps should always operate between 30%-70% of capacity. Metering pumps that do not meet these size specifications should not be installed. Oversized metering pumps should not be used because serious overfeeds (i.e., overfeed that exceeds 4 mg/L) can occur if they are set too high. Conversely, undersized metering pumps can cause erratic fluoride levels.

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11. Priming switches on the metering pumps shall be spring-loaded to prevent pumps from being started erroneously with switches in the priming position.
12. Flow meter-paced systems should not be installed unless the rate of water flow past the point of fluoride injection varies by more than 20%.
13. A master meter on the water service line must be provided so that calculations can be made to confirm that the proper amounts of fluoride solution are being fed.
14. Fluoride solutions shall not be injected in a point of negative pressure.
15. The fluoride feed line(s) should be either color-coded, when practical, or clearly identified by some other means. Color-coding helps prevent possible errors when taking samples or performing maintenance. The pipes for all fluoride feed lines should be painted light blue with red bands. The word "fluoride" and the direction of the flow should be printed on the pipe or, for small piping, on the wall beside the pipe.
16. The dilution water pipe shall end at least two pipe diameters above the highest water level in the solution tank, or an adequate backflow prevention device must be provided. All hose connections within reach of the fluoride feed equipment should be provided with a hose-bib vacuum breaker.
17. Cross-connection controls must be provided that conforms to state regulations in 10 CSR 60-11.010.
18. Hose bibs and water supply piping to supply potable water for clean up of spills shall be provided in both the chemical feed and storage areas. The number of hose bibs and their location depend upon the size of the areas served.

c. Sodium Fluoride Saturator Systems. Sodium fluoride systems are not recommended but may be considered on a case-by-case basis with the department's written approval**.**

d. Fluorosilicic Acid Systems.
1. To reduce the hazard to the water plant operator, fluorosilicic acid (hydrofluosilicic acid) must not be diluted. Instead, the metering pump specified shall permit the use of undiluted fluorosilicic acid for water plants of any size.
2. No more than a 30-hour supply of fluorosilicic acid should be connected at any time to the suction side of the chemical feed pump. All systems using bulk storage tanks must have a day tank.
3. Day tanks or direct acid-feed carboys/drums shall be located on scales; daily weights shall be measured and recorded. Volumetric measurements, such as marking the side of the day tank, are not adequate for monitoring acid feed systems.
4. Full spill containment shall be provided for bulk storage tanks. Furthermore, bulk storage facilities cannot be located over plant treatment basins, pumping wells, transfer wells or clearwells.
5. Bulk storage tanks inside buildings; day tanks and unsealed carboys shall be vented to the outside with a vent approved by the department.

e. Dry Fluoride Feed Systems.
1. Dry feeders (both volumetric and gravimetric) must be provided with a

solution tank.

2. Solution tanks shall be sized according to Water Fluoridation: A Manual for Engineers and Technicians published by the Centers for Disease Control and Prevention.
3. A mechanical mixer should be used in every solution tank of a dry feeder when sodium fluorosilicate is used.
4. Scales must be provided for weighing the amount of chemicals used in the dry feeder.

f. Testing Equipment.

1. Surface water plants should use the ion electrode method of fluoride analysis.
2. A magnetic stirrer should be used in conjunction with the ion electrode method of fluoride analysis.
3. The colorimetric method (SPADNS) of fluoride analysis can be used where no interference occurs or where the interferences are consistent (e.g., from iron, chloride, phosphate, sulfate, or color).

g. Secondary controls. Secondary control systems for fluoride chemical feed devices may be required by the department as a means of reducing the possibility for overfeed.

h. Protective equipment. The use of personal protective equipment (PPE) is required when fluoride compounds are handled or when maintenance on fluoridation equipment is performed. The employer should develop a written program regarding the use of PPE and make this a part of the operation plan for the system. Safety procedures should be routinely followed and enforced.

1. Fluorosilicic acid.

   At a minimum, the operator shall be provided with the following personal protective equipment for normal maintenance and operation of fluorosilicic acid facilities:

   a. Gauntlet neoprene gloves with cuffs, which should be a minimum length of 12 inches (30.5 cm);
   b. Full face shield and splash-proof safety goggles; and
   c. Heavy-duty, acid-proof neoprene apron or acid-proof clothing and shoes.

   Specific procedures for handling leaks in bulk storage tanks must be included in the required, system, emergency operations plan.

   A safety shower and an eye wash station must be available and easily accessible.

2. Sodium fluoride or sodium fluorosilicate. An eye wash station should be available and easily accessible. The operator shall be provided with the following personal protective equipment:

   a. A National Institute for Occupational Safety and Health (NIOSH)/Mine Safety and Health Administration (MSHA)- approved, N-series particulate respirator (i.e., chemical mask) with a soft rubber face-to-mask seal and replaceable cartridges (49-51);
   b. Splash-proof safety goggles;
   c. Gauntlet neoprene gloves, which should be a minimum length of 12 inches (30.5 cm); and

d. Heavy-duty, acid-proof neoprene apron.

3. Dust control.

a. Provision must be made to minimize fluoride dust when transferring dry fluoride compounds from shipping containers to storage bins or hoppers. Feeder hoppers shall be provided with an exhaust fan and dust filter that place the hopper under a negative pressure. Air exhausted from the fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

b. Provision shall be made for disposing of empty bags, drums, or barrels in a manner that will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the hosing of floors.

5.5. Ozone

5.5.1. Ozone Generator

a. Capacity.

1. The production rating of the ozone generators shall be stated in pounds per day and kW-hr per pound at a maximum cooling water temperature and maximum ozone concentration.
2. The design shall ensure that the minimum concentration of ozone in the generator exit gas will not be less one percent, by weight.
3. Generators shall be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time, which can result in premature breakdown of the dielectrics.
4. The production rate of ozone generators will decrease with a variation in the supply temperature of the coolant throughout the year. Curves or other data shall be used to determine production changes due to the temperature change of the supplied coolant. The design shall ensure that the generators can produce the required ozone at maximum temperature.
5. Appropriate ozone generator backup equipment must be provided.

b. Electrical. The generators can be low, medium or high frequency type. Specifications shall require that the transformers, electronic circuitry and other electrical hardware be proven, high quality components designed for ozone service.

c. Cooling. The required water flow to an ozone generator varies with the ozone production. Normally unit design provides a maximum cooling water temperature rise of 2.8°C (5°F). The cooling water must be properly treated to minimize corrosion, scaling and microbiological fouling of the water side of the tubes. A closed loop cooling water system is often used to ensure proper water conditions are maintained. Where cooling water is treated cross connection control shall be provided to prevent contamination of the potable water supply.

d. Materials. To prevent corrosion, the ozone generator shell and tubes shall be constructed of Type 316L stainless steel**.**

5.5.2. Ozone Contactors.

The selection or design of the contactors and method of ozone application depends on the purpose for which the ozone is being used.

a. Bubble Diffusers. Where disinfection is the primary application, a minimum of two contact chambers, each equipped with baffles to prevent short-circuiting and induce countercurrent flow, shall be provided. Ozone shall be applied using porous-tube or dome diffusers.
b. The minimum contact time shall be ten minutes. A shorter contact time may be approved if justified by appropriate design and CT considerations.
c. For ozone applications in which precipitates are formed , such as with iron and manganese removal, porous diffusers should be used with caution.
d. Where taste and odor control is of concern, multiple application points and contactors shall be considered.
e. Contactors should separate closed vessels that have no common walls with adjacent rooms. The contactors must be kept under negative pressure and sufficient ozone monitors shall be provided to protect worker safety. Placement of the contactors where the entire roof is exposed to the open atmosphere is recommended. In no case shall the contactor roof be a common wall with a separate room above the contactors.
f. Large contact vessels should be made of reinforced concrete. All reinforcement bars shall be covered with a minimum of 1.5 inches of concrete. Smaller contact vessels can be made of stainless steel, fiberglass or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level.
g. Where necessary a system shall be provided between the contactors and the off-gas destruction unit to remove froth from the air and return the other to the contactors or other location acceptable to the reviewing authority. If foaming is expected to be excessive, then a potable water spray system shall be placed in the contactors head-space.
h. All openings into the contactors for pipe connections, hatchways, etc. shall be properly sealed using welds or ozone resistant gaskets such as Teflon or Hypalon.
i. Multiple sampling ports shall be provided to enable sampling of each compartment's effluent water and to confirm CT calculations.
j. A pressure/vacuum relief valve shall be provided in the contactors and piped to a location where there will be no damage to the destruction unit.
k. The diffusion system should work on a countercurrent basis such that the ozone is fed at the bottom of the vessel and water is fed at the top of the vessel.
l. The depth of water in bubble diffuser contactors should be a minimum of 18 feet. The contactors should have a minimum of 3 feet of freeboard to allow for foaming.
m. All contactors shall have provisions for cleaning, maintenance and drainage of the contactors. Each contactor compartment shall be equipped with an access hatchway.
n. Aeration diffusers shall be fully serviceable by either cleaning or replacement.
o. Other Contactors. Other contactors, such as the venturi or aspirating turbine mixer contactors, may be approved by the department provided adequate ozone transfer is achieved and the required contact times and residuals can be verified.

5.5.3. Ozone Destruction Unit.

A system for treating the final off-gas from each contactor must be provided in order to meet safety and air quality standards. Acceptable systems include thermal destruction and thermal/catalytic destruction units. In order to reduce the risk of fires, the use of units that operate at lower temperature is encouraged, especially where high purity oxygen is the feed gas. The maximum allowable ozone concentration in the discharge is 0.1 PPM (by volume). At least two units shall be provided which are each capable of handling the entire gas flow. Exhaust blowers shall be provided in order to draw off-gas from the contactors into the destruction unit. Catalysts must be protected from froth, moisture, and other impurities that may harm the catalyst. The catalyst and heating elements shall be located where they can easily be reached for maintenance.

5.5.4. Piping Materials.

Only low carbon 304L and 316L stainless steels shall be used for ozone service with 316L the preferred.

5.5.5. Joints and Connections.

Connections on piping used for ozone service are to be welded where possible. Connections with meters, valves, or other equipment are to be made with flanged joints with ozone resistant gaskets, such as Teflon or Hypalon. Screwed fittings shall not be used because of their tendency to leak. A positive closing plug or butterfly valve plus a leak-proof check valve shall be provided in the piping between the generator and the contactors to prevent moisture reaching the generator.

5.5.6. Instrumentation.

Pressure gauges shall be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet of the ozone generators and contactors and at the inlet to the ozone destruction unit. Electric power meters should be provided for measuring the electric power supplied to the ozone generators. Each generator shall have a trip which shuts down the generator when the wattage exceeds a certain preset level. Dew point monitors shall be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow for proper adjustment of the dryer cycle. Where there is potential for moisture entering the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, post-generator dew point monitors shall be used. Air flow meters shall be provided for measuring air flow from the desiccant dryers to each of other ozone generators, air flow to each contactor and purge air flow to the desiccant dryers. Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generators feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water. Water flow meters shall be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply. Ozone monitors shall be installed to measure ozone concentration in both the feed-gas and off-gas from the contactors and in the off-gas from the destruction unit. For disinfection systems, monitors shall also be provided for monitoring ozone residuals in the water.

The number and location of ozone residual monitors shall be such that the amount of time that the water is in contact with the ozone residual can be determined. A minimum of one ambient ozone monitor shall be installed in the vicinity of the contactors and a minimum of one ambient ozone monitor shall be installed in the vicinity of the generator. Ozone monitors shall also be installed in any areas where ozone gas may accumulate.

5.5.7. Alarms.

The alarm/shutdown systems listed here should be considered at each installation.

a. Dew point shutdown/alarm. This system should shut down the generator in the event the system dew point exceeds-60 °C (-76 °F).
b. Ozone generator cooling water flow shutdown/alarm. This system should shut down the generator in the event that cooling water flow decreases to the point that generator damage could occur.
c. Ozone power supply cooling water flow shutdown/alarm. This system should shut down the power supply in the event that cooling water flow decreases to the point that damage could occur to the power supply.
d. Ozone generator cooling water temperature shutdown/alarm. This system should shutdown the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.
e. Ozone power supply cooling water temperature shutdown/alarm. This system should shutdown the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.
f. Ozone generator inlet feed-gas temperature shutdown/alarm. This system should shutdown the generator if the feed-gas temperature is above a preset value.
g. Ambient ozone concentration shutdown/alarm. The alarm should sound when the ozone level in the ambient air exceeds 0.1 PPM or a lower value chosen by the water supplier. Ozone generator shutdown should occur when ambient ozone levels exceed 0.3 PPM (or a lower value) in either the vicinity of the ozone generator or the contactor.
h. Ozone destruct temperature alarm. The alarm should sound when temperature exceeds a preset value.

5.5.8. Safety.

The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 PPM (by volume). Noise levels resulting from the operating equipment of the ozonation system shall be controlled to within acceptable limits by special room construction and equipment isolation. High voltage and high frequency electrical equipment must meet current electrical and fire codes. Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs. A portable purge air blower that will remove residual ozone in the contactors prior to entry for repair or maintenance should be provided.

5.5.9. Construction Considerations.

Prior to connecting the piping from the desiccant dryers to the ozone generators the air compressors should be used to blow the dust out of the desiccant. The contactors should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactors and checking for pressure losses. Connections on the ozone service line should be tested for leakage using the soap-test method.

5.6. Ozone Feed Gas Preparation

Feed gas can be air, high purity oxygen, or oxygen enriched air. Air handling equipment on conventional low pressure air feed systems shall consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and particulate filters. Some “package” ozonation systems for small systems may work effectively operating at high pressure without the refrigerant dryer and with a “heat-less” desiccant dryer. In all cases the design engineer must ensure that the maximum dew point of -60°C (-76° F) will not be exceeded at any time. For oxygen-feed systems, dryers typically are not required.

5.6.1. Air Compression.

a. Air compressors shall be of the liquid-ring or rotary lobe, oil-less positive displacement type for smaller systems or dry rotary screw compressors for larger systems.
b. The air compressors shall have the capacity to simultaneously provide for maximum ozone demand, provide the airflow required for purging the desiccant dryers (where required) and allow for standby capacity.
c. Air feed for the compressors shall be drawn from a point protected from rain, condensation, mist, fog, and contaminated air sources to minimize moisture and hydrocarbon content of the air supply.
d. A compressed air after-cooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.
e. A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a break-down.

5.6.2. Air Drying.

a. Dry, dust free and oil- free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation, and to prevent damage to the generator dielectrics. Sufficient drying to maximum dew point of -60° C (-76 degrees ° F) must be provided at the end of the drying cycle
b. Drying for high pressure systems may be accomplished using heatless desiccant dryers only. For low pressure system, a refrigeration air dryer in series with heat-reactivated desiccant dryer shall be used.
c. A refrigeration dryer capable of reducing inlet air temperature to 4° C (40° F) shall be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type.
d. For heat-reactivated desiccant dryers, the unit shall contain two desiccant filled towers complete with pressure relief valves, two four-way valves and a heater. In addition, external type dryers shall have a cooler unit and blowers. The size of the unit shall be such that the specified dew point will be achieved during a minimum adsorption style time of 16 hours while operating at the maximum expected

moisture loading conditions.

e. Multiple air dryers shall be provided so that the ozone generation is not interrupted in the event of dryer breakdown.

g. Each dryer shall be capable of venting “dry” gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are “on-line.”

5.6.3. Air Filters.

a. Air filters shall be provided on the suction side of the air compressors, between the air compressors and the dryers and between the dryers and the ozone generators.

b. The filter before the desiccant dryers shall be of the coalescing type and be capable of removing aerosol and particulate larger than 0.3 microns in diameter. The filter after the desiccant dryer shall be of the particulate type and be capable of removing all particulate greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

5.6.4 Air Preparation Piping.

Piping in the air preparation system can be common grade steel, seamless copper, stainless steel or galvanized steel. The piping must be designed to withstand the maximum pressures in the air preparation system.

Chapter 6 -- Minimum Construction Requirements for Pumping Facilities

6.0 General

This section applies to public water systems that construct or make major alterations to pumping facilities and well houses.

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6.01. National Standards.

a. Unless otherwise noted in this document, design and construction of the following components shall be in accordance with the latest edition of the American Water Works Association (AWWA) Standards:

1. AWWA Standard E101 for Vertical Turbine Pumps-Line Shaft and Submersible Types;
2. AWWA Standard C500 for Metal Seated Gate Valves for Water Supply Service;
3. AWWA Standard C509 for Resilient Seated Gate Valves for Water Supply Service;
4. AWWA Standard C504 for Rubber Seated Butterfly Valves;
5. AWWA Standard C507 for Ball Valves 6-inch through 48-inch;
6. AWWA Standard C508 for Swing-Check Valves for Water Works Service 2-inch through 24-inch;
7. AWWA Standard C115 for Flanged Ductile Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges;
8. AWWA Standard C200 for Steel Water Pipe 6-inch and Larger;
9. AWWA Standard C206 for Field Welding of Steel Water Pipe;
10. AWWA Standard C207 for Steel Pipe Flanges for Water Works Services Sizes 4-inch through 144-inch; and
11. AWWA Standard C220 for Stainless-Steel Pipe 4-inch and Larger.

b. Centrifugal Pumps.

Unless otherwise noted in this document, centrifugal pumps shall be designed and constructed in accordance with the latest (ANSI-HI) American National Standards Institute and Hydraulic Institute Standards, except that the following requirements shall be observed:

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1. Larger stuffing boxes for mechanical seals shall be used;
2. Solid Shafts shall be used for close coupled, end suction, horizontal centrifugal pumps to eliminate bending motion caused by the impeller; and
3. Close coupled, end suction, horizontal centrifugal pumps should not be used if the L^3/D^4 ratio is greater than 60 where L is shaft length and D is shaft diameter.

c. Electrical Equipment.

Unless otherwise noted in this document, design and construction of all electrical equipment and all wiring associated with pumping facilities shall be in accordance with the latest NFPA 70 National Electric Code published by the National Fire Protection Association and shall be in accordance with any applicable local electric code or portion of a local electric code that is more stringent than the National Electric Code. Electric equipment should be provided to allow easy connection of permanent or portable electric generator to operate the pumps. Electric motors shall at least meet the standards of the National Electrical manufacturers Association (NEMA) for premium motors. In addition, pump motors shall meet applicable requirements of the Federal Energy Policy and Conservation Act and rules of the United States Department of Energy on efficiency requirements of electric motors.

d. Buildings.
Pumping facilities should be housed in above ground, fully enclosed, climate controlled buildings with adequate exterior access for pump maintenance. Unless otherwise noted in this document, design and construction of buildings that house pumping facilities should be such that the structure will have a NFPA Type I construction rating as outlined in the latest NFPA Standards on Types of Building Construction published by the National Fire Protection Association. Interior walls of pumping rooms, buildings, or chambers shall be of water resistant material to allow damage free cleaning.

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e. Ladders, Stairways, Handrails and other Safety Equipment.
Unless otherwise noted in this document, design and construction of all ladders, stairways, handrails, safety cages, and other safety appurtenances for pumping facilities shall conform to the latest federal Occupation Safety and Health Administration (OSHA) Regulation 29 CFR, Part 1910, Subpart D, Occupational Safety and Health Standards, General Industry Standards. These safety appurtenances shall also conform to any applicable local ordinances, codes, standards or portion thereof that are more stringent than the OSHA standards.

f. Other Pumping Equipment.
Pumps, valves, pipe, and appurtenances other than those listed above in the national standards may be used in pumping facilities provided the engineer demonstrates that the components have sufficient strength, durability, and functionality. Some specialty components not listed in the national standards may be more appropriate, such as stainless steel, nickel-copper alloy or low-zinc bronze bolts for flanged piping to reduce corrosion or globe valves when throttling is needed. In these cases, the most appropriate component is recommended. Solvent welded polyvinylchloride (PVC) pipe shall not be used.

6.02. Other General Standards.

a. Pumping facilities shall be designed to maintain the sanitary quality of the pumped water. No pumping station shall be subject to flooding. Subsurface pits or pump rooms should be avoided.

b. Electrical efficiency of the pumping system should be considered in pump design and overall electrical usage and electrical cost as affected by electrical peak demand considerations should be minimized.

c. Preliminary pump curves and system curves including suction pressures shall be provided as part of a complete hydraulic analysis showing conditions for all possible combinations of pumps in operation. This information shall be provided as part of the plans and specification submittal.

d. As part of the final as-built plans or certification submitted by the engineer for pumping facilities projects, the department shall be provided with manufacturer, model number, impeller size, horsepower, voltage and amperage requirements for both unsteady state (startup) and steady state conditions, rotational speed(s), electrical phase requirements, pump curve showing both head versus flow characteristics and efficiency characteristics, and life expectancy with proper maintenance for each pump and motor. The department shall also be provided with final cost of the project, excluding land and easement.

6.1. Location.

6.1.1. The pumping station shall be so located that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system, and protection against fire, flood, vandalism, or other hazards.

Deleted: terrorist acts,

6.1.2. Site protection shall include the following:

a. For finished water pumping stations, the pump operating floor of the pumping station shall be elevated to a minimum of four feet above the 100 year return frequency flood elevation or four feet above the highest historical flood elevation, whichever is higher, or protected to such elevations;

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b. Finished water suction wells, pumping wells, wet wells, or finished water storage facilities associated with a pumping facility shall not be located in an area that floods.

c. Raw water pumping facilities that must be located in areas that flood shall have necessary motor and electrical controls and non-submersible pumps and motors located a minimum of four feet above the 100 year return frequency flood elevation or four feet above the highest historical flood elevation, whichever is higher.

d. Raw water pumping facilities that must be located in areas that flood shall have electric service designed to provide continued operation of the pumping facilities during floods.

e. The pumping station shall be readily accessible to operating and maintenance personnel at all times unless the overall system design allows the station to be out of service for the period of inaccessibility.

f. The area around the pumping station shall be graded to route surface water drainage away from the station.

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6.1.3. Pumping stations shall be designed to prevent vandalism, and entrance by unauthorized personnel or animals. See section 2.5. for specific requirements.

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6.1.4. The size of the site selected, the location of the pump building, and the electrical service and panels shall be designed to accommodate the use of portable or permanent power generators and their accessories.

6.1.5. Pumping stations shall be provided with all-weather driveways and parking areas to allow off-road parking and access for equipment during maintenance.

6.2. Pumping Stations.

6.2.1. Finished and raw water pumping stations.

a. Both finished and raw water pumping stations shall be designed and constructed to include adequate space for the installation of additional units that may be needed during the next 20 years and adequate space around each unit to allow safe servicing;

b. Buildings should be of durable construction with a life expectancy with proper maintenance of 100 or more years. This shall include structural design to withstand all 100- year return frequency weather related events except a direct hit by a tornado;

c. Buildings shall have outward opening doors;

d. Floors shall be at least six inches above finished grade;

e. Underground structures shall be water-proofed;

f. All floors shall be drained in such a manner that the quality of potable water shall not be endangered. All floors shall slope at least 1:40 vertical to horizontal (3 inches per 10 feet) to a suitable drain;

g. Water from pump gland drainage shall be discharged through a suitable outlet without discharging to the floor;

h. Buried pumping stations should be avoided. When buried pumping stations cannot be avoided they shall be considered as confined spaces with required entry procedures.

i. All accessways to buried pumping stations shall be fitted with a locking device, and shall be framed at least six inches, but no more than one foot above the final ground surface. In addition, accessways shall be fitted with a solid, water-tight, hinged cover. The accessway cover shall be self supporting when open and shall overlap the framed opening and extend down around the frame at least two inches.

j. Accessways to the buried pumping stations shall be sufficiently large enough to allow easy removal of pumps and other equipment in the station. For large pumping stations, additional accessways may be required over each pump.

k. Power lifting equipment shall be specified as part of the required pumping station equipment. Lifting equipment may be either stand-alone or truck mounted and shall be sized to remove the heaviest piece of equipment in the buried pumping station.

l. All other openings and penetrations (vents, piping, power service, control wires, etc.) into the buried pumping stations shall be water tight.

m. Vents shall be provided for buried pumping stations and shall extend at least eighteen inches above the final ground surface. Vents shall either be capped or downturned to prevent water entrance and shall be screened to prevent insects from entering the station.

n. Switches to operate the interior station lights and the ventilation fan in buried pumping stations shall be located at the entrance to the pumping station where they can be turned on prior to entrance.

o. Access ladders to buried pumping stations shall be equipped with extendable ladder safety posts to facilitate safe access to the ladder.

p. For buried pumping stations, stairs or ships ladder with safety rails should be provided instead of straight fixed ladders.

q. A power ventilation system shall be provided for buried pumping stations and sized to properly vent the confined space.

r. A floor sump and sump pump or drain to daylight shall be provided in buried pumping stations with the discharge extended above ground and discharging away from the pumping station. The floor shall slope to the sump and shall not allow ponding of water.

s. Manufactured buried metal pumping stations shall be equipped with exterior cathodic protection and the location of the sacrificial anode packs shall be clearly marked.

t. The operating floors of manufactured metal pumping stations shall be covered with non-slip material to prevent falls.

u. Buildings and structures for raw water pumping facilities that must be located in areas that flood shall be constructed of material and in a manner that will withstand flood forces and effects with minimal damage;

v. Buildings and structures for raw water pumping facilities that must be located in areas that flood shall have walls designed and sealed to prevent water seepage and have all openings and penetrations through the walls either sealed or designed to be sealed to prevent water intrusion including drains, pipe, cable and electric wire penetrations, and so forth;

w. Raw water pumping facilities that must be located in areas that flood shall be capable of being remotely operated and monitored. Buried hard wired connections for remote operation proved unreliable during past major floods.

x. Raw water pumping facilities that must be located in areas that flood shall be provided with sumps and pumps to allow the automatic safe removal of water from the facility during a flood. Sumps shall be sized to allow the installation of pumps large enough to protect the facility during a flood;

y. Raw water pumping facilities that must be located in areas that flood and must be accessed by boat shall have permanent stairs, ladders, landings, alternative access ways, and any other provisions necessary for safe access and egress during a flood.

z. Hose bibs to provide water for cleaning shall be provided; and

aa. Smooth nose sample tap constructed of brass, bronze, or stainless steel shall be located on each pump discharge to allow bacterial sampling.

6.2.2. Suction wells.

Suction wells shall be designed and constructed to protect the quality of water pumped including the following:

a. Suction wells shall be water tight;

b. Suction wells shall have floors sloped to permit removal of water and solids;

c. Suction wells shall be covered or otherwise protected against contamination; and

d. Suction wells shall have baffles, adjustable false walls, or other appurtenances necessary to prevent vortexing.

6.2.3. Motor and Pump Installation and Removal.

a. Pump stations shall be designed and constructed to allow the safe, efficient removal and reinstallation of each motor and pump including:

1. Crane ways, hoist beams with hoists, eyebolts, or other facilities shall be provided for lifting, removing, and reinstalling each equipment item that weighs 50 or more pounds; and
2. The buildings shall be equipped with openings in floors, roofs, or walls to allow safe, efficient removal and reinstallation of equipment. These openings shall be properly hatched, grated, or doored to protect the building from weather or unauthorized entry when not in use.

b. Maintenance equipment, including a tool board, should be provided.

6.2.4. Stairways/Ladders.

Pump stations shall be equipped with permanent stairways and ladders to allow access to every part of the building that must be entered for operation or maintenance of the equipment. Stairways shall be provided to areas that must be routinely entered.

6.2.5. Heating, Ventilation, Lighting, and Dehumidifying.

Pump stations shall be equipped with heating, ventilation, lighting, and dehumidification for the safe, efficient operation and maintenance of the equipment and reasonable comfort of the operator including the following:

a. Heating equipment shall be installed in facilities that are manned less than one hour per day to maintain a temperature of 40 degrees Fahrenheit (40º F) or higher during the 100-year return frequency coldest temperature;

b. Heating equipment shall be installed in facilities that are manned one hour per day or more to maintain a temperature of 65 degrees Fahrenheit (65º F) or higher during the 100-year return frequency coldest temperature;

c. Ventilation (and air conditioning if needed) shall be provided that achieves the following:

1. Inside temperature and outside temperature shall not have a differential of more than 10º F during the 100-year return frequency hottest temperature;
2. Inside temperature shall be maintained lower then the highest allowable ambient operating temperature for each pump motor, and electrical component;
3. All rooms, compartments, pits, and enclosures below ground level shall be power vented to provide at least six air changes per hour. Switches to operate the ventilation equipment and lights shall be located at the entrance to the below ground facility and shall be placed to allow these to be operated without entering the facility; and
4. All rooms, compartments, pits, and enclosures that are subject to accumulation of hydrogen sulfide (H_2S), chlorine gas (Cl_2), radon (Rn), or other hazardous substances shall have air changes sufficient to maintain levels of each hazardous substance below "Threshold Limit Values of Airborne Contaminants for 1970" of the American Conference of Governmental Industrial Hygienists, but in no case less than six air changes per hour; and

Deleted: the eight hour daily exposure Occupation Safety and Health Administration (OSHA) limit

d. Lighting shall be provided so that every part of the facility is well lit and all instrument readings and all maintenance and operation can be performed without additional lighting. Light fixtures shall be located where bulbs can be readily changed. Exterior lighting shall be provided to deter vandalism and to allow safe access and maintenance work after dark.

6.2.6. Dehumidification.

Dehumidification should be provided if ventilation is not adequate to prevent condensation that is causing a safety hazard or is damaging equipment or controls.

6.2.7. Manned pumping stations.

Pumping stations that are manned for one hour or more per day shall be equipped with potable water, lavatory, and toilet facilities. Plumbing must be installed so as to prevent contamination of the public water supply and wastes shall be discharged in accordance with regulations in 10 CSR 20.

6.3. Pumps.

6.3.1. Sizing

a. Pumps shall be sized as part of the overall public water system design to meet maximum day pumping demand, diurnal peak flow, instantaneous peak flow, fire flow (if provided), and minimal flows.

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b. Submittals for approval shall include a system curve covering the entire flow and head range at which each pump is expected to operate.

c. Pump specifications shall state the discharge flow and head, horsepower and efficiency of each pump.

d. At least two pumping units shall be provided and the pumps shall be capable of meeting maximum day pumping demand with the largest capacity pump out of service.

e. When pumping units are required to operate over a broad flow range, a sufficient number of single speed pumps with different flow capabilities or variable speed pumps shall be provided. If single speed pumps are provided, they shall be sized to provide the entire range of flow and to avoid excessively short run cycles.

f. Where more than one single speed pump will operate simultaneously, system curves showing head and flow conditions of each combination of pumps shall be submitted. The effect of simultaneous operation on all pumps involved shall be explained in the submittals for approval.

g. Frequently used single speed pumps should be provided in pairs.

h. Variable speed pumps shall be provided in pairs.

i. Any submittal for variable speed or frequency pumps shall state whether the pumps will operate to provide a constant pressure, a constant flow or will operate to allow both flow and pressure to vary.

j. Any submittal for variable speed or frequency pumps shall include system curves covering the entire flow range and shall specify the base horsepower and base speed required. Pump specifications shall designate the minimum, maximum, and normal frequency, head and capacity points at which the pump is expected to operate. Pump specifications shall designate the pump efficiency and horsepower range at which the pump is expected to operate.

k. All specifications for variable frequency drives shall require fault protection for power circuit components and harmonic distortion protection to protect the drive and power system ahead of the drive.

Deleted: . Before any variable speed pump is approved, variable torque curves showing that the pump motor will produce enough torque and volt/frequency/torque curves shall be submitted.

6.3.2. Single tower storage

Public water systems that have pressure zones served by a single tower shall have pumps able to meet all water demands and maintain adequate main pressures while the tower is out of service for maintenance. These pumps shall be equipped with permanent pressure relief devices.

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6.3.3. Pumping unit design and construction.

a. Pump motors shall have ample capacity to supply the peak demand without overload.

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b. Pumps should be designed to operate in the head/flow range of maximum efficiency.

c. Prime movers driving pumps shall be able to operate against the maximum head.

d. Specifications shall include spare parts and tools needed for routine maintenance and repair of pumps and motors.

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e. Control equipment shall have the proper heater and overload protection for the air temperature extremes expected.

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f. Pumps that generate 30 pounds per square inch (psi) or more surge pressure during start up or shutdown or which generate surges that result in pressure below 20 per square inch gage (20 psig) anywhere in the distribution system shall be equipped with water hammer/surge protection or prevention devices and these devices shall be designed to reduce surge pressure to less than thirty pounds per square inch (30 psi) and maintain distribution pressure of thirty five pounds per square inch gage (35 psig) or more. Variable speed drives and soft-start/soft-stop controls are an acceptable alternative to mechanical surge control devices.

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g. Where large elevation differences exist, a mechanical surge control device may be necessary as a safety measure during power failure.

6.3.4. Suction Lift.

a. Suction lift should be avoided if possible.

b. Suction lift shall be within allowable limits of the pump and preferably less than 14 feet.

c. Provisions shall be made for priming pumps providing suction lift. Prime water must not be of lesser sanitary quality than the water being pumped. Means shall be provided to prevent back siphonage. When an air operated ejector is used, the screened intake shall draw clean air from a point at least ten feet above the ground or other possible contamination unless the air is filtered by an apparatus approved by the department. Vacuum priming may be used.

6.4. Additional Requirements for Booster Pumps.

In addition to meeting the pump requirements in section 6.3. of this document, booster pumps shall meet the criteria in this section.

6.4.1. Booster Pumping Station

a. Each booster pumping station shall contain not less than two pumps with capabilities such that peak demand and fire flow, if provided, can be satisfied with the largest pump out of service.

b. The booster station shall also include equipment such as multiple sets of pumps with different capacities, variable speed pumps, hydropneumatic tanks, or other equipment to meet the full range of flow needed if elevated storage is not provided to stabilize pressure on the portion of the distribution system served.

c. Booster stations serving areas not provided with elevated storage shall provide hydropneumatic storage sized to meet the requirements of Section 7.4.4.

d. Booster stations serving areas that are not provided with elevated storage that serve more than 50 connections shall not use hydropneumatic storage as the only storage.

e. Booster stations serving areas not provided with elevated storage and that server more than 100 connections shall have permanent power generation installed to serve the pumping station. The power generation facilities shall be sized to allow normal operation of the booster pumps, their controls and all pumping station accessories and appurtenances.

f. Booster stations serving areas not provided with elevated storage shall be designed to maintain a minimum main pressure of 35 psi throughout the area served.

6.4.2. Booster Pumps Drawing from Storage Tanks

6.4.2.1. Booster pumps drawing directly from storage tanks shall be located and controlled to achieve the following:

a. Pumps will not produce negative pressure in the suction line;

b. All pumps shall be valved and piped so that each pump can be isolated and removed without draining the storage facilities and with the remaining pumps in service;

c. Automatic or remote control devices shall have a range between start and cutoff pressure which will prevent excessive cycling; and

d. System design shall allow storage facilities serving pumping stations to be removed from service for maintenance while maintaining normal service to the area served.

Deleted: d. All booster pumping stations shall contain a totalizing meter.¶

6.4.2.2. Suction lines should be buried but shall be protected from freezing temperatures if not buried.

6.4.3. Inline booster pumps

Inline booster pumps are pumps that do not draw water directly from storage.

a. Distribution systems with inline booster pumps shall not cause main pressures to drop below 35 psig in any part of the system delivering water to the booster station.

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b. All pumps shall be accessible for servicing and shall be valved and piped so that each pump can be isolated and removed with the remaining pumps in service.

6.4.4. Individual home booster pumps

Individual home booster pumps shall not be allowed for any individual service from the public water supply mains unless approved by the department. Approval will generally be considered only for temporary service until properly designed distribution system improvements can be made to eliminate the low pressure area.

6.4.5. Automatic Stations

All automatic stations should be provided with automatic signaling apparatus that will report when the station is out of service. All remote-controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance.

6.5. Appurtenances

6.5.1. Valves.

Pumps shall be adequately valved to permit satisfactory operation, maintenance, and repair of the equipment. If foot valves are necessary, they shall have a net valve area of at least 2½ times the area of the suction pipe and they shall be screened. Each pump shall have a positive-acting check valve on the discharge side between the pump and the shut-off valve.

6.5.2. Piping.

In general, piping shall:

a. Be designed so that the friction losses will be minimized;
b. Not be subject to contamination;
c. Have watertight joints;
d. Be protected against surge or water hammer;
e. Be such that each pump has an individual suction line or that the lines shall be so manifolded that they will ensure similar hydraulic and operating conditions;
f. Be equipped with a hose bib for cleaning; and
g. Be equipped with smooth-nose sampling taps constructed of brass, bronze, or stainless steel on both the suction and discharge.

6.5.3. Gages and meters.

Each pump discharge header shall be equipped with a rate of flow meter that totals the gallons of water pumped and each pump shall:

a. have a standard pressure gage on its discharge line;
b. have a compound gage on its suction line; and
c. have a totaling elapsed time of operation meter.

Design should consider continuous monitoring devices on gauges, meters and other instruments.

Deleted: **b. Pressure control valves shall be required for reducing water hammer or surges that equal or exceed 30 pounds per square inch and shall be required if the surge results in pressure below 20 pounds per square inch gage anywhere in the distribution system.¶**

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Deleted: have recording gages in the stations with capacities of 0.5 million gallons per day () or larger; an

Deleted: Should have a totaling time of operation meter.

6.5.4. Water Seals.

a. Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped.

b. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal shall:
   1. Be provided with a break tank open to atmospheric pressure;
   2. Have an air gap of at least one inch or two pipe diameters, whichever is greater, between the feeder line and the spill line of the tank; or
   3. Provided with a reduced pressure principle backflow prevention assembly.

6.5.5. Controls.

Pumps, their prime movers, and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision shall be made for alternating pumps. Provision shall be made to prevent energizing the motor in the event of a backspin cycle. Electrical controls shall be located above grade.

6.5.6. Power.

For their own protection, all water systems should make an arrangement for back-up power. Systems serving a population of 3,300 or more shall make arrangements for back-up power, and include these arrangements in their emergency operating plan. When power failure would result in cessation of minimum essential service, power supply should be provided from at least two independent sources or a standby or an auxiliary source should be provided. Portable auxiliary power generators may be used if they are sized to generate sufficient power for normal operation of the pumping station. Pumping stations to be served by portable power generators should be equipped with permanent in-place electric connections and controls for operating on the power generator. Systems with multiple booster pumping stations should have a power supply from at least two independent sources, permanent onsite standby or auxiliary power sources or portable generators for each booster pumping station that serves more than 100 connections.

6.5.7. Water pre-lubrication.

When automatic pre-lubrication of pump bearings is necessary and an auxiliary direct drive power supply is provided, the pre-lubrication line shall be provided with a valved bypass around the automatic control so that the bearings can, if necessary, be lubricated manually before the pump is started, or the pre-lubrication controls shall be wired to the auxiliary power supply.

6.5.8. Oil or Grease Lubrication.

All lubricants which come into contact with potable water shall be certified for conformance to ANSI/NSF Standard 60

6.6. Well Houses

Well houses are considered pumping stations and shall meet the design specifications of this chapter, except that duplicate pumping units (wells) are not required as per 6.3.1 of this chapter.

a. Well houses shall conform to the "Site location and security consideration" requirements of this document.

b. Requirements for sample taps are specified in Chapter 2 "Plant Sample Taps", and Chapter 3 "Discharge Piping" of this document. When possible, sample taps should be installed at or over a sink, with one for raw well water and one for finished water after treatment, to provided a safe work area for collecting samples and allow the water to be safely routed to a drain.

c. Where hose bibs are provided as a source of water for cleaning, they shall be protected by atmospheric vacuum breakers.

d. When chemical treatment is applied at a well, separate rooms with adequate ventilation to the outside should be provided to reduce corrosive vapors within the well house, notwithstanding other requirements specified in Chapter 5 of this document.

e. When possible, well houses should be provided with adequate access in and out of the well house when the well is being serviced.

f. Well houses shall be provided with adequate drainage, at a minimum a floor drain or a flap gate in the wall. Drains shall not be directly connected to a sanitary sewer or storm sewer, but shall be provided with an acceptable air gap or drain to daylight. The discharge end of the drain shall be protected by a corrosion resistant screen to prevent entrance by insects or vermin.

Chapter 7 -- Minimum Construction Standards for Finished Water Storage Tanks and Reservoirs

7.0. General Design and Construction Standards

7.0.1. AWWA Standards for Unpressurized Tanks and Reservoirs

Unless otherwise noted in this rule, unpressurized tanks and reservoirs for finished water storage shall be designed and constructed in accordance with the latest edition of the American Water Works Association (AWWA) standards, as follows:

Welded Steel Tanks for Water Storage	AWWA Standard D100
Coatings for Steel Water Storage Tanks	AWWA Standard D102
Factory Coated Bolted Steel Tanks for Water Storage	AWWA Standard D103
Automatically Controlled Impressed Current Cathodic Protection for the Interior of Steel Water Tanks	AWWA Standard D104
Wire and Strand Wound Circular, Pre-stressed Concrete Water Tanks	AWWA Standard D110
Circular Pre-stressed Concrete Water Tanks with Circumferential Tendons	AWWA Standard D115

7.0.2. Parameters for Unpressurized Tanks and Reservoirs for Finished Water Storage

These parameters should be considered during the design of unpressurized tanks and reservoirs for finished water storage.

a. Tank Design

Tank design should be part of a unified long range, engineering design that includes wells, treatment plants, high service pumps, booster pumps, and distribution mains. System design shall describe how normal system flows and pressures will be maintained when the storage facility is out of service for maintenance. Since tanks have an approximate useful life of 50 years, the design should consider future growth, including the elevation of areas likely to be developed during the useful life of the tank. Current service area and future service area should be divided into appropriate pressure zones with operating pressures between 35 psig and 100 psig. All of these items should be reflected in the design to ensure the tank will not become obsolete during its useful life.

Deleted: The tank should be designed to maintain water temperature above 32° F during the winter weather that would result in the lowest storage water temperature during a seven-day period taken from the most recent 100-year period of weather data or statistically calculated as a 100-year return frequency. An energy balance should be calculated using the following parameters: average winter (December, January, February) daily flow into and out of the tank; winter diurnal flow pattern into and out of the tank; water temperature into the tank under the winter design conditions; heat transfer between the water layer and air layer in the tank; heat transfer rate through the tank wall and any insulating layer; heat transfer from the outside tank surface to the atmosphere based on wind speed and air temperature from the winter design conditions; solar energy input to the tank during daylight under the winter design conditions; and radiation heat loss from the tank to the sky during night time under winter design conditions. If winter design conditions are not available, a reasonably conservative estimate can be made using the high and low temperature from the record low temperature day from the nearest U. S. weather station with 100 years of record for one of the seven days, using the average coldest winter day from the nearest U. S. Weather station with 100 years of record for the other six days, using sunrise/sunset times and sun angle for the seven days centered on the winter solstice, using average wind speed for December – February from the nearest U. S. Weather station with 100 years of record, and assuming 50% cloud cover for sky conditions. This energy balance should be used to set the winter tank turnover rate, winter pump ON/pump OFF elevations, inlet and outlet designs to ensure mixing to minimize ice formation, insulation requirements (if appropriate) and heater requirements (if appropriate).

b. Storage Water Quality

Long detention times and poor water circulation can lead to the loss of disinfectant residuals, taste and odor complaints, formation of disinfection byproducts, and other water quality issues including microbial contamination. The following design features shall be evaluated to improve circulation and maintain optimum storage water quality:

1) Storage facilities that float on the system may not develop complete mixing. This can lead to stagnant zones where the water age exceeds the average water age in the facility. Separate inlet and outlet lines can be used to promote circulation if check valves are installed to force flow into one line and out the other. A bypass line and valves on both the inlet and outlet lines must be installed to allow the storage facility to be isolated and drained for inspection and maintenance. The orientation, placement, size and separation of inlet and outlet lines shall be designed to promote mixing;
2) If detention time is needed for disinfection, separate inlet and outlet lines shall be provided.
3) Specialty mechanical mixers may be used to obtain and maintain proper mixing to prevent stagnation. Mixers shall not be installed in facilities used to provide disinfection detention;
4) Check valves or duckbilled valves may be installed on combined inlet and outlet lines to promote mixing. This arrangement shall not be considered as separate inlet and outlet lines for the purpose of disinfection detention;
5) The storage facility should be designed to turn over a sufficient percentage of the stored water daily to minimize water quality problems;
6) Temperature differences within a large storage facility can cause thermal stratification. Design of the storage facility shall include minimizing thermal stratification; and
7) Studies have shown storage located near the center of a pressure zone will have lower water ages than those located near the edge of a pressure zone. Distribution system models to evaluate potential water age and system hydraulics should be used to evaluate storage facility sites.

Deleted: The tank should be designed to turn over a sufficient percentage of the stored water daily to minimize

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Deleted: water quality problems. This percentage may vary with local condition, but a 25% daily turnover is suggested as a default value. Note that additional turnover may be required for winter operations to minimize freezing. Separate inlet and outlet lines should be provided and placed to promote maximum circulation. If detention time is needed for disinfection, separate inlet and outlet lines shall be provided.

c. Provisions for sampling

Sampling taps shall be provided to allow for collection of water quality samples for bacteriological and chemical analysis, from representative portions in the storage tank. At a minimum, sample taps shall be provided that allow for samples of the water quality from the top, center and lower portions of the storage tank. The sample taps shall be easily accessible.

7.0.3. Location

a. With exception of foundations using piers and pilings, the bottom of foundations or footings for reservoirs, standpipes, ground storage tanks and elevated tanks shall be above the 100 year return frequency flood level or the highest known historic flood elevation, whichever is higher.

b. Tops of footings or foundations for elevated tanks, ground storage tanks and standpipes shall be at least one foot above the finished grade.

c. With exception of foundations using piers and pilings, the bottom of foundations or footings for reservoirs, ground storage tanks, standpipes, and elevated tanks shall be above the true ground water level.

d. The bottom of reservoirs, ground storage tanks, and standpipes should be placed above the normal ground surface. When the bottom must be placed below ground surface, the storage facility shall be constructed of concrete with a foundation drainage system provided, and special design consideration shall be given to assure water tightness. Sewers, drains, standing water and similar sources of contamination must be kept at least 50 feet from the storage facility, except that specially constructed gravity sewers may be located no closer than 20 feet. These specially constructed gravity sewers shall be made of restrained or mechanical joint water main pipe pressure tested in place to 50 PSIG of pressure without leakage. No part of a steel storage tank shall be located below ground surface.

e. The top of the reservoirs shall not be less than two feet above the normal ground surface except that clear wells under filters may be exempted when the total design gives the same protection. The area surrounding a reservoir shall be graded in a manner that will prevent surface water from standing within 50 feet of it.

f. The area surrounding ground storage tanks, standpipes, and elevated tanks shall be graded and sloped away from each facility and graded in a manner that will prevent surface water from standing within 20 feet of it. The area beneath legged elevated tanks shall be graded and sloped in a manner that will prevent surface water from standing around footings or foundations or within the area.

g. When selecting sites for reservoirs, ground storage tanks, standpipes, and elevated tanks, provisions shall be made to conduct overflow water away from the site without damaging surrounding property.

h. The site selected shall be of sufficient size to allow adequate space for trucks and other equipment necessary for maintenance of the storage facility. The site shall be provided with all weather driveways and parking areas to allow off road parking and access for equipment during maintenance.

i. When selecting a site for a painted elevated tank or standpipe, the proximity of residences, businesses, highways, public roads, parking lots, and buildings and their affect on the ability to paint the facility shall be considered. In general, an elevated tank or standpipe should be no closer to a residence, business, highway, public road, parking lot, or building than the overall height of the facility.

j. Electric control buildings and pump and well houses shall not be located beneath a legged elevated tank, but should be at least fifty feet from any elevated tank or standpipe.

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Deleted: Steel storage tanks shall not be located below the ground surface.

Deleted: The area surrounding or beneath ground level storage tanks, standpipes and elevated tanks shall be graded to prevent surface water from standing within 20 feet of a footing or foundation.

k. The proximity of elevated tanks and standpipes to airports and aviation flyways and the requirements of the Federal Aviation Administration shall be considered.

7.0.4. Protection of Finished Water Storage Structures

All finished water storage structures shall be protected from trespassing, unauthorized access and vandalism. Protection shall include at least the following:

a. Locked hatches and other access openings;
b. Physical barriers to entrance of ladders; and
c. Security fencing with locked gates.
d. Exterior lighting that adequately lights the perimeter of the facility; and
e. Multiple uses of storage facilities or their structures shall be approved by the department, and should be part of the original design.

Deleted: Steel storage tanks shall not be located below the ground surface.¶

Deleted: 7.0.4. Roofs on Unpressurized Finished Water Storage Structures¶
All unpressurized finished water storage structures shall have suitable watertight roofs that prevent entrance of birds, animals, insects, and excessive dust. The roof shall be well drained. Downspouts shall not enter or pass through the storage structure.

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See also section 2.5, Security Measures.

7.0.5. Vents on Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures shall be vented. Overflows shall not be considered vents. Open construction between the sidewall and roof is not permissible. Vents shall meet the following criteria:

a. Vents shall be sized with sufficient capacity to pass air so that the maximum flow of water entering or leaving the tank will not cause excessive pressure or vacuum. Maximum flow of water leaving a storage facility shall include the maximum fire flow to be provided in the area served by the facility plus the maximum peak domestic flow plus the peak commercial flow. Vents for storage used to provide filter backwash shall be sized to pass the maximum backwash flow rate. Consideration should be given to the flow rate produced by a catastrophic large main failure near the facility. Resistance of air flow caused by the vent screens shall be considered in sizing the vents;
b. Vents shall be designed to exclude precipitation and surface water, shall be screened to exclude birds, insects, and animals, and shall terminate a minimum of 24 inches above the roof. At least one screen covering the entire opening shall be no coarser than 18 mesh;
c. Pressure vacuum-screened vents or a separate pressure-vacuum relief mechanism shall be provided that will operate in the event that the screens frost over or become clogged. The screens or relief mechanism shall not be damaged by the occurrence and shall return automatically to operating position after the blockage is cleared. The primary purpose of the vents is to prevent catastrophic structural failure of the tank caused by pressure differential. No alterations shall be made to vents to interfere with this primary purpose; and
d. Clearwell vents shall vent to the outside.

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Deleted: Eighteen mesh noncorrodible screen may be used. The finished water storage structure shall also be equipped with a pressure-vacuum relief mechanism that will operate should the finer mesh screens be frost plugged or clogged with foreign material.

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7.0.6. Overflows on Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures shall be provided with an overflow. Overflows shall meet the following criteria:

a. Overflows shall be sized to permit the waste of water in excess of the maximum filling rate with a head not more than six inches above the lip of the overflow. Resistance of flow through the screen and flap shall be considered in sizing the overflow;

b. To prevent water and ice damage to the tank and its surroundings, overflows shall be brought down to an elevation no closer than 12 inches and no greater than 24 inches above the ground surface. Overflows should terminate at the bottom with an elbow directed away from the foundation, and shall discharge over a drainage inlet structure or splash plate. Overflows shall not be extended below ground or directly connected to a sewer or storm drain;

c. Overflows that discharge to a drainage inlet structure shall terminate at least 5-inches above the highest lip of the inlet structure;

d. Overflows shall be protected from entrance of insects, birds or animals by an 18-mesh non-corrodible screen, a tight fitting counterweighted flap valve, or a duck-billed check valve. Flap valves and check valves should be designed and operate such that they will close completely, seal tightly and not stick open. To confirm the integrity of the screens or mechanical devices and check valves, the devices shall be located where they can be inspected as part of routine maintenance.

e. Overflows should be diverted to minimize property damage and inconvenience to adjacent property owners; and

f. Overflows shall be provided for all clearwells. Overflows for clearwells shall be extended to daylight or discharged to a sump or manhole through an air gap. The discharge pipe of the sump or manhole shall discharge to daylight or the sump or manhole shall be equipped with a pump or pumps sized to carry the maximum probable overflow rate.

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7.0.7. Freeze Protection for Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures and their appurtenances including the internal structural components riser pipes, overflows, vents, and hatches shall be designed to prevent freezing that will interfere with proper functioning or cause structural damage to the storage vessel. Design shall be based on a 100 year return frequency extended low temperature period and average wind velocity. Equipment used for freeze protection that will come into contact with the potable water shall meet ANSI/NSF Standard 60 or be approved by the department. If a water circulation system is used, it is recommended that the circulation pipe should be located separately from the riser pipe. Water level controls shall be flexible and accurate enough to allow operators to easily adjust tower operation to weather conditions.

7.0.8. Catwalks

Every catwalk over finished water in a storage structure shall have a solid floor with raised edges so designed that shoe scrapings and dirt will not fall into the water.

7.0.9. Corrosion Protection

1. Proper protection shall be given to metal surfaces. Tanks constructed of steel, wrought iron, or other metals subject to corrosion shall have all metal interior and exterior surfaces painted.
   a. Consideration should be given to using lead free paint for exterior surfaces.
   b. Exterior paint color should be chosen to help manage the temperature of stored water to reduce freezing or reduce excessive summer temperatures as needed.
   c. Interior paint systems shall be certified for drinking water use under the latest ANSI/NSF Standard 61. Interior paint must be applied, cured, and used in a manner consistent with the ANSI/NSF approval.
   d. Interior paint systems shall be properly applied and cured so that after curing, the coating shall not transfer any substance to the water which could be toxic or cause taste or odor problems. After painting and proper curing are completed and the tank is filled, but prior to placing it in service, an analysis for volatile organic compounds should be conducted on the water in the tank to establish that the coating is properly cured.
2. Tanks constructed of corrosion resistant metals shall be designed to meet the same structural requirements outlined in section 2.1.1. and shall not be required to be painted. Corrosion resistant metals shall be chosen to resist corrosion from all naturally occurring chemicals in the water stored, all chemicals added as part of water treatment including the addition of chlorine and other disinfectants, and the natural atmosphere including current and expected future air pollutants in the area.

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Deleted: Exterior paint should contain less than 100 milligrams of lead per kilogram of dried paint to prevent removed paint from being classified as a hazardous waste.

Deleted: and shall not transfer any substance to the water that results in a violation of a maximum contaminant level or secondary contaminant level outlined in 10 CSR 60, Chapter 4. Curing should also be done to eliminate tastes and odors.

Deleted: the water that exhibits such odors shall be tested for each paint constituent that is listed in 10 CSR 60, Chapter 4 prior to placing the tank in service.

7.0.10. Drains on Unpressurized Tanks and Reservoirs

Unpressurized tanks and reservoirs shall be equipped with a drain and have facilities for collecting bacteriological samples.

a. Elevated tanks and standpipes with a nominal capacity of 30,000 gallons or more that provide pressure by gravity shall be equipped with a fire hydrant with one pumper (steamer) nozzle of approximately 4½ inches in diameter and two hose nozzles of approximately 2½ inches diameter. The piping, valves, and fire hydrant shall be designed and constructed to allow the tank to be taken off line and drained through the fire hydrant.
b. Other above ground tanks shall be equipped with a fire hydrant or flush hydrant. The piping, valves, and hydrant shall be designed and constructed to allow the tank to be taken offline and drained through the flush hydrant or fire hydrant.
c. No drain shall have a direct connection to a sewer or storm drain. The design and construction shall allow tanks and reservoirs to be taken offline, drained, cleaned, repaired, and painted without causing loss of pressure in the distribution system.
d. Reservoirs, clearwells, and other below ground storage facilities shall either be equipped with drains to daylight or sumps with floors sloped to the sumps to facilitate inspection and cleaning. Drains shall be designed to prevent

contamination from entering the storage facility. At a minimum, the discharge end of the drain shall pass through a headwall and be equipped with a tight fitting counterweighted flap valve designed so that it cannot open more than ninety degrees from horizontal to prevent them from sticking open. Access hatches shall be installed over sumps to allow access for installing pumps.

7.0.11. Roofs and Sidewalls on Unpressurized Tanks and Reservoirs

Unpressurized tanks and reservoirs shall have roofs and sidewalls designed and constructed to preserve the quality of the water stored.

a. All unpressurized finished water storage structures shall have suitable watertight roofs that prevent entrance of birds, animals, insects, and excessive dust and pollen.

b. Roofs shall be well drained. Roof downspouts shall not enter or pass through the storage structure.

c. The roof and side walls must be water tight with no openings except properly constructed vents, manways, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.

d. Any pipes running through the roof or side wall of a finished water storage structure must be welded or properly gasketed in metal tanks. In concrete tanks these pipes shall be connected to standard wall castings. These wall castings should have seepage rings imbedded in the concrete.

e. All penetrations through roofs or walls of storage facilities for installing a cathodic protection system, level sensors, level controls, power to tank mixing systems, or for any other purpose shall be water tight.

f. Openings in a structure roof or top designed to accommodate control apparatus or pump columns shall be curbed and sleeved with proper additional shielding to prevent the access of surface or floor drainage water into the structure.

Deleted: Valves and controls shall be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir.

g. Valves and controls shall be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir.

h. Unpressurized finished water storage structures shall be designed and constructed to allow convenient access to the interior for cleaning, safety venting and maintenance.

i. At least two (2) hatches or manways must be provided above the waterline at each water compartment where space permits.

j. All roof hatches or manways shall be framed at least six inches above the surface of the roof and shall be fitted with a solid water tight gasketed cover.

k. No roof hatch or manway shall be smaller than twenty four inches in diameter or square and should be no less than thirty inches in diameter or square.

l. At least one roof or top hatch shall be fitted with a solid water tight, gasketed, and hinged cover which overlaps the framed opening and extends down around the frame at least two inches, and shall have a locking device. This hatch shall be at least 30 inches in diameter or square.

m. All other hatches and manways shall be bolted and gasketed to provide a watertight seal, or conform to the above requirements.

n. Access hatches and manways for ground level structures shall be elevated at least 24 inches above the top of the facility or finished ground surface, whichever is higher and shall be fitted with a solid, water tight, gasketed hinged cover which overlaps the framed opening and extends down around the frame at least two inches, and shall have a locking device.

Deleted: Downspouts shall not enter or pass through the storage structure.

7.0.12. Discharge Pipes

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7.0.12. Access to Unpressurized Finished Water Storage Structures¶
Unpressurized finished water storage structures shall be designed and constructed to allow convenient access to the interior for cleaning and maintenance. The number, location, and spacing of hatches and manways shall conform to the federal Occupational Safety and Health Administration (OSHA) regulation 29 CFR, Part 1910. Roof or top hatches shall be framed at least six inches above the surface of the roof or top at the opening, shall be fitted with a solid, water tight, hinged cover which overlaps the framed opening and extends down around the frame at least two inches, and shall have a locking device.¶

The discharge pipes from all reservoirs shall be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

7.0.13. Safety Devices at Unpressurized Finished Water Storage Structures

Unpressurized tanks and reservoirs shall be equipped with safety devices to allow safe inspection, repairs, maintenance, and painting.

a. Ladders, handrails, safety cages and other safety appurtenances shall conform to the federal OSHA regulation 29 CFR, Part 1910 Subpart D. These safety appurtenances shall also conform to any applicable local ordinances, codes, or standards that are more restrictive than OSHA standards. No wire, cable or other device shall be attached to the ladders, handrails or other safety appurtenances in such a manner that will obstruct or impair the safe use of these devices.
b. Ladders, ladder guards, balcony railings, and safely located entrance hatches shall be provided where applicable. Safety climbing devices shall be provided on the ladders of all storage facilities not equipped with safety cages.
c. Railings or handholds shall be provided on elevated tanks where persons must transfer from the access tube to the water compartment or the roof ladder to the access hatch or manway.
d. Elevated tanks with riser pipes over eight inches in diameter shall have protective bars over the riser opening or a safety handrail around the riser opening inside the tank. Because protective bars are frequently dislodged by ice thereby defeating their purpose, a safety handrail around the riser opening is the preferred method of protection.
e. Warning lights should be provided on standpipes and elevated storage tanks and shall be provided when required by the Federal Aviation Administration (FAA) or local codes.
f. Cables, power conduits, antenna brackets or similar devices shall be installed inside properly constructed conduits. Properly designed brackets must secure these to the storage structure.

7.0.14. Disinfection of Unpressurized Finished Water Storage Structures

Disinfection of unpressurized finished water storage tanks and reservoirs following construction, repairs, painting, or other maintenance shall be done in accordance with the latest edition of the AWWA Standard for Disinfection of Water-Storage Facilities, AWWA C652.

a. At least one sample shall be analyzed to indicate microbiologically satisfactory water before the facility is placed into operation.

b. Disposal of chlorinated water from the tank shall be in accordance with Missouri Clean Water Commission requirements to protect aquatic life.

7.0.15. Antenna, Wires, Lighting and Cables

The primary purpose of finished water storage facilities is to store adequate amounts of potable water for the public in a safe usable manner. Any secondary use of finished water storage structures shall not interfere with the safe use, inspection, operation, and maintenance of these facilities for their primary purpose. The installation of appurtenances, such as antenna, shall be done in a manner that ensures no damage to the tank, coatings or water quality, or corrects any damage that occurred. The following shall be considered when designing antenna installations on finished water storage facilities.

a. Antenna and their wires or cables shall not be installed where they obstruct, restrict, or interfere with the safe use of any painter's vent, ladder, catwalk, access tube, hatch, manway, or accessway. Cables or wires shall not be directly attached to any ladder, handrail or step and shall not be installed behind any access ladder or in any other manner that interferes with the safe use of a ladder.

b. Antenna shall not be attached to any part of an access ladder, overflow pipe, vent, access hatch, or manway.

c. A structural evaluation shall be done of the location on the storage facility and of the method of attaching the antenna and its cables or wires that includes wind loads and increased ice and snow loads as well as the weight of the equipment. The evaluation shall determine the need for stiffeners, plates to distribute loads or other structural improvements needed to support the antenna and their wires or cables.

d. The ability to sandblast and paint the storage facility without removing an antenna or its cables shall be considered. Cables should be supported on brackets that stand off of the storage tank enough to allow sand blasting and painting beneath the cables. Small wires and cables should be installed in conduits to prevent damage during sandblasting and to allow them to be adequately secured. The additional costs of removing antenna, cables and wires to allow the storage facility to be properly prepared and panted shall be considered with deciding to install an antenna.

e. Cables and wire shall be adequately supported and secured by specific brackets that minimize cable and wire movement and do not allow wires or cables to rub against the storage structure. Cable brackets, trays, ladders, or raceways shall be material that will not create corrosion issues. Attaching a cable or wire with tape or plastic zip ties to existing brackets of storage appurtenances shall not be approved.

f. Bolts holding on antenna and cable brackets shall not penetrate the walls or roofs of water holding portions of storage facilities or tubular legs of multicolumn elevated tanks.

g. Clamps or bands used to attach equipment to storage facilities shall be sealed, provided with gaskets, or otherwise designed and installed to prevent corrosion and to protect the coating beneath them from damage.

h. Any welded attachments to a finished water storage facility shall be seal welded to prevent corrosion. Both interior and exterior coatings shall be repaired after any welding done on a water storage facility.
i. Consideration shall be given to shielding and grounding of cables and wires to prevent corrosion to the storage facility.
j. Base transmission cabinets, buildings, or other antenna ground equipment shall not be located directly beneath an elevated tank where it will interfere with the deployment, staging, or movement of manpower and equipment for maintenance. Base transmission cabinets or other antenna ground equipment located inside of the dry pedestal of an elevated tank shall be located so that they do not interfere with the access or operation and maintenance of any of the tank components.
k. As the number, size and types of antenna and their cables increase, their probable adverse affect on the storage facility increases. Where multiple large antenna exist or are planned for a storage facility, the structural integrity of the entire facility and its foundation shall be evaluated to assure that it will safely withstand the added weight plus any extra snow, ice, and wind loads.
l. As the number and types of antenna and their cables increase, routing of cables and wires can become a maintenance and safety issue. Where multiple antennas exist or are planned for a storage facility, an overall plan for routing cables and wires shall be provided.
m. Cell phone and other antenna transmitting intense radiofrequency radiation are an acute health and safety hazard to anyone climbing on the storage facility. Specific warning signs shall be placed at the access ladders to these facilities. Equipment shall be accessible to the system operators to turn off radiofrequency radiation emitting antenna during inspection or maintenance of the storage facility or other antenna on the storage facility.

7.0.16. Vaults

Vaults for valves, piping, and other equipment associated with finished water storage facilities shall meet the following requirements.

a. Vaults shall be considered as confined spaces with required entry procedures, and may be permit-required confined spaces.
b. A power ventilation system should be provided for each vault and sized to properly vent the confined space.
c. Vaults shall be water tight. Open dirt, gravel or rock bottomed vaults shall not be approved.
d. All openings and penetrations for vents, piping, power service, control wires, etc into the vault shall be water tight.
e. All accessways to vaults shall be fitted with a locking device, shall be framed at least six inches, but no more than one foot above the final ground surface, and shall be fitted with a solid, water tight, hinged cover. The accessway cover shall be self supporting when open and shall overlap the framed opening and extend down around the frame at least two inches.
f. Accessways to vaults shall be sufficiently large enough to allow easy removal of valves and other equipment from the vault.

g. Accessways to vaults shall be located so that an operator does not have to drop or climb onto piping or equipment to enter the vault to protect both the equipment and the operator from damage.
h. Vaults shall be fitted with permanent access ladders equipped with extendable ladder safety posts to facilitate safe access to the ladder and the vault.
i. A floor sump shall be provided in each vault and the floor shall slope to the sump. The sump shall either be provided with a drain to daylight or with a sump pump that has a discharge extended above ground and discharging away from the vault.
j. Vents for vaults shall extend at least eighteen inches above the final ground surface and shall either be capped or downturned to prevent water entrance and shall be screened to prevent insects from entering the vault.
k. Interior lighting and heating facilities should be considered for vaults.
l. All vaults shall have sample taps and appropriately sized pressure gauges installed on the storage side of the piping.
m. Vaults containing altitude valves or water level controls shall have appropriately sized pressure gauges on both the influent and effluent piping of the vault
n. Piping in vaults shall be installed far enough above the floor and below the roof of the vault to facilitate paining.
o. Adequate permanent supports shall be installed to support valves and piping in the vault.
p. Sufficient influent and effluent valves shall be installed to allow equipment in the vault to be removed without draining the storage facility.

7.1. Tanks and Reservoirs for Finished Water Storage

7.1.1. Fire Protection.

The primary purpose of a public water system is to produce and deliver adequate quantities of safe drinking water to the public. Failure to fulfill this purpose has serious adverse affects on public health. Use of the public water systems for any other purpose such as irrigation, recreation, industrial production, or fire protection is of secondary importance to the primary purpose. No secondary use of a public water system shall be allowed to degrade the safety and sanitary quality of the drinking water or system.

Public water supplies that provide fire protection should be capable of providing the calculated maximum needed fire flow within its distribution system for a duration of two hours up to a maximum flow of 3500 GPM. The Insurance Services Office (ISO) Guide for Determination of Needed Fire Flow is not a design criteria, but has been shown to reasonably approximate actual fire flow needed to suppress a fire in a real-life situation. Some communities have local fire codes that set fire suppression requirements that differ from the ISO guide. Designers should consult with local authorities before designing a system or making improvements intended to provide fire protection.

For new water systems or improvements within existing distribution systems, it is customary to provide for the needed fire flow for one major fire in the design area using

Deleted: Public water supplies that provide fire protection shall have finished water storage tanks, reservoirs, and other facilities with sufficient capacity to provide

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Deleted: the needed fire flow for the length of fire duration and shall provide adequate storage to meet diurnal peak flow or one day's average demand with fire flow being considered. Public water supplies that provide fire protection shall determine design needed fire flow and design supply works capacity in accordance with the latest Fire Suppression Rating Schedule published by Insurance Services Organization Inc. (ISO). ¶

Deleted: aThe minimum allowable design needed fire flow and design supply works capacity are 250 gallons per minute for a fire duration of two hours.b.Other commonly used design needed fire flows with the equivalent fire durations are listed in section 7.5.¶

the ISO guide. It is very unusual for existing distribution systems to be capable of providing every needed fire flow within its service area. Therefore, this guide applies only to proposed new or proposed improvements to areas of water distribution systems intended to provide fire protection. Private and public protection at properties with needed fire flows that exceed 3500 GPM should be individually evaluated with consideration given to additional methods of fire protection other than the public water distribution system.

Needed fire flows are met by a combination of flows from water sources and from elevated or pumped water storage.

a. The reliability of the flow from sources and pumps shall be considered when sizing water storage facilities.
b. Systems shall be capable of providing designed pumped flows with the largest pump or well out of service.
c. The age of the water and its impact on water quality shall be considered when designing water storage. Generally, at least one quarter of the water in each storage facility should be turned over every day.
d. Water stored for fire protection shall be in addition to that stored for normal average daily usage.
e. Public water supplies that provide fire protection shall have finished water storage tanks, reservoirs, and other facilities with sufficient capacity to provide minimum required fire flow for the length of fire duration and shall provide adequate storage to meet diurnal peak flow with fire flow being considered.
f. Systems that do not provide a minimum fire flow of 250 GPM for fire duration of two hours are not designed to provide any fire protection.

7.1.2. No Fire Protection.

Public water supplies that do not provide fire protection shall have sufficient finished water storage to meet the minimum design operating pressure and flow for the diurnal flow pattern on the design maximum usage day with all well pumps, treatment plants, high service pumps, booster pumps, or other equipment that affect pressure and flow in operation. This can be achieved by the following methods:

a. Provide finished water elevated storage with nominal capacity equal to or greater than one day's average demand. For standpipes, the volume above the elevation, which provides 35 psig at the tower base, shall be counted as nominal capacity.
b. Provide ground level finished water storage with nominal capacity equal to or greater than one day's average demand. Duplex or variable speed high service pumps shall be provided with this option. The high service pumps shall have a capacity capable of meeting design instantaneous peak flow and of maintaining a minimum pressure of 35 PSIG throughout the service area with the largest pump out of service. Emergency power generation facilities shall be provided to assure that water outages or low water pressures do not occur. Note the volume above low level withdrawal pump shut down is counted as nominal capacity.
c. Estimate or document diurnal flow pattern and design maximum day's usage.

Deleted: Public water supplies that do not provide the fire protection shall have sufficient finished water storage to meet the minimum design operating pressure and flow for the diurnal flow pattern on the design maximum usage day with all well pumps, treatment plants, high service pumps, booster pumps, or other equipment that affect pressure and flow in operation. This can be achieved by the following methods:

Deleted: Storage facilities shall have sufficient capacity, as determined from engineering studies, to meet one day's average demand. This can be achieved by the following methods:

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Deleted: c. Estimate or document diurnal flow pattern and design maximum day's usage. Calculate the minimum nominal finished water storage needed to maintain design operating pressure and flow with all well pumps, treatment plants high service pumps, booster pumps or other equipment that affect pressure and flow in operation. The minimum storage needed will vary for each public water supply but 25% of design maximum day's usage is a reasonable default value.

Deleted: The one day's average demand storage requirement may be reduced when the source, treatment and pumping facilities have sufficient capacity with redundancy and standby power to supplement peak demands of the system.

Calculate the minimum nominal finished water storage needed to maintain design operating pressure and flow with the designed production of well pumps, treatment plant high service pumps, booster pumps or other equipment that affect pressure and flow provided. If multiple high service pumps, booster pumps or other equipment are not designed to routinely operate simultaneously, their simultaneous operation shall not be considered when calculating needed storage.

d. Provide hydropneumatic storage as outlined in section 7.4.

7.1.3. Storage Capacity for Unpressurized Storage Facilities

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Deleted: Tanks

Storage facility capacities estimated in engineering design studies and finalized in engineering final plans and as-built plans submitted to the department shall include the elevation and volume data specified here.

Deleted: Tank and reservoir

7.1.3.1. Elevations

a. For preliminary engineering designs, the following elevations must be provided to the nearest 1.0 feet above mean sea level (MSL).
   1. Elevation of the finished grade (ground surface) at the base of the storage facility.
   2. Overflow elevation.
   3. Head range and low water elevation.
   4. Corresponding elevations of existing storage facilities in the same pressure zone.
   5. Elevation of original ground level for storage reservoirs.

Deleted: the msl elevations may be estimated from United States Geological Survey (USGS) 7.5 minute Quadrangle maps but the public water supply, the engineer and the funding agency must recognize that this method of estimating elevations is subject to significant error and corrections of preliminary errors in elevation on elevated tanks may substantially change the cost of the project. T

b. Plans and specifications submitted for construction approval shall include the following elevations expressed to the nearest 1.0 feet above mean sea level (MSL).
   1. Elevation of the finished grade (ground surface) at the base of the storage facility.
   2. Elevation of the top of the footings and foundations.
   3. Elevation of low water level and head range.
   4. Overflow elevation.
   5. Withdrawal pumps, filling pump(s) and control valve(s) on and off elevations.
   6. Freeboard between the top of the overflow and the ceiling of the storage facility.

Deleted: Withdrawl

c. As-built plans or shop drawings shall be submitted and shall include the following elevations expressed to the nearest 0.1 feet above mean sea level (MSL).
   1. Elevations of the finished grade (ground surface) at the base of the storage facility.
   2. Elevation of the top of the footings and foundations.
   3. Elevations of low water level and head range.
   4. Overflow elevation.

5. Withdrawal pumps, filling pump(s) and control valve(s) on and off elevations.
6. Elevation of the top of the storage facility.
7. Elevation of the bottom of elevated tank bowl.
8. Freeboard between the top of the overflow and the ceiling of the storage facility.

7.1.3.2. **Volumes**

a. For preliminary engineering design studies the following storage volumes shall be provided.

1. The total storage volume of the storage facility .
2. The maximum effective (usable) storage volume. This is the volume between overflow and the low water level, which provides the minimum 35 psig at the service connection to the highest customer served by gravity by the storage facility.
3. The operating volume. This is the volume between the normal operating levels of the facility. The volume between the lowest elevation at which the filling pumps start (or the filling control valves open) and the elevation at which the filling pumps stop (or the filling control valves close). If withdrawal pumps are used this "operating volume" is the volume between fill pump stop level and the elevation at which the withdrawal pumps normally stop.
4. The volume used for disinfection contact time. This is the volume of water below the lowest shut-off level of the clearwell, pumping well, ground storage tank and other pumped storage or the lowest allowed normal level of the storage facility.

b. Plans and specifications submitted for construction approval shall include the following:

1. The total storage volume of the reservoir or tank.
2. The maximum effective (usable) storage volume. This is the volume between overflow and the low water level, which provides the minimum 35 psig at the service connection to the highest customer served by gravity by the storage facility.
3. The operating volume. This is the volume between the normal operating levels of the facility. The volume between the lowest elevation at which the filling pumps start (or the filling control valves open) and the elevation at which the filling pumps stop (or the filling control valves close). If withdrawal pumps are used this "operating volume" is the volume between fill pump stop level and the elevation at which the withdrawal pumps normally stop.
4. The volume used for disinfection contact time. This is the volume of water below the lowest shut-off level of the clearwell, pumping well, ground storage tank and other pumped storage, or the lowest allowed normal level of the storage facility.

Deleted: Withdrawl

Deleted: All of the elevations specified here, expressed to the nearest 0.1 feet above mean sea level (msl), shall be provided for all nonpressurized tanks. For preliminary engineering designs, the msl elevations may be estimated from United States Geological Survey (USGS) 7.5 minute Quadrangle maps but the public water supply, the engineer and the funding agency must recognize that this method of estimating elevations is subject to significant error and corrections of preliminary errors in elevation on elevated tanks may substantially change the cost of the project. For final engineering plans and as-built plans, the msl elevations shall be determined by measurement from a known USGS or department elevation monument.¶
1. Elevation of the finished grade (ground surface) at the base or under the tank.¶
2. Elevation of the actual tank bottom.¶
3. Elevation of the bottom capacity level (point at which the tank normally discharges).¶
4. Elevation at which the withdrawal pumps shut down because of low level (applicable to tanks/reservoirs with withdrawal pumps).¶
5. Elevation which will provide twenty pounds per square inch gage (20 psig) static pressure at finished grade at the base of the tank (applicable to standpipes that provide pressure by gravity).¶
6. Elevation which will provide twenty pounds per square inch gage (20 psig) static pressure at the highest surface elevation in the area to be served by the tank (applicable to standpipes that provide pressure by gravity.¶
7. Elevation at which the filling pump starts (or the filling control valve opens).¶
8. Elevation at which the filling pump stops (or filling control valve closes).¶
9. Elevation at which the tank/reservoir begins to overflow.¶
10. Elevation at the top of the tank or reservoir (or roof of the tank or reservoir).

Deleted: reservoir or tank

Deleted: in the pressure zone

Deleted: between the average operating level of the facility and the top of the outlet pipe.

Deleted: in the pressure zone

Deleted: between the average operating level of the facility and the top of the outlet pipe.

c. As-built plans or shop drawings shall be submitted and shall include the actual volumes for the following:

1. The total storage volume of the storage facility. For elevated storage tanks a volume/elevation curve shall be submitted.
2. The maximum effective (usable) storage volume. This is the volume between overflow and the low water level, which provides the minimum 35 psig at the service connection to the highest customer served by gravity by the storage facility.
3. The operating volume. This is the volume between the normal operating levels of the facility. The volume between the lowest elevation at which the filling pumps start (or the filling control valves open) and the elevation at which the filling pumps stop (or the filling control valves close). If withdrawal pumps are used this "operating volume" is the volume between fill pump stop level and the elevation at which the withdrawal pumps normally stop.
4. The volume used for disinfection contact time. This is the volume of water below the lowest shut-off level of the clearwell, pumping well, ground storage tank and other pumped storage, or the lowest allowed normal level of the storage facility.
5. The volume between the elevation that will provide 20 PSIG static pressure at the highest customer served by gravity by the storage facility, and the elevation at which the storage facility begins to overflow is the fire suppression capacity for storage facilities.

7.1.4. Costs

As part of the final engineering certification on a finished water storage facility construction project, the engineer shall submit the final cost of the facility excluding land or easement costs.

7.2. Plant Storage

At a minimum, plant water storage (any storage following treatment and prior to distribution) shall be adequate to provide all required disinfection contact time. These requirements are in addition to the applicable requirements listed in subsections 7.0. and 7.1.

7.2.1. Filter Backwash.

Wash water tanks are finished water storage facilities and shall meet all of the applicable requirements for storage facilities. Wash water tanks shall be sized to provide the filter backwash at the design filter backwash rate. The wash water tanks, pumps, and finished water storage must be designed to allow backwashing several filters in rapid succession in order to meet the most extreme plant operational problems expected. Plants with three or fewer filters should have sufficient wash water capacity to backwash all filters in rapid succession. The time and rate required to refill wash water tanks and their impact on plant operation shall be provided in the submittals to the department. Special

Deleted: in the pressure zone

Deleted: between the average operating level of the facility and the top of the outlet pipe.

Deleted: All of volumes specified here, expressed to the nearest 100 gallons, shall be provided for all unpressurized tanks.¶
1. Volume between the elevations of the bottom capacity level (point at which the tank normally discharges) and the elevation at which the tank begins to overflow (applicable to elevated tanks). This is the nominal capacity for elevated tanks.¶
2. Volume between the elevation of the bottom capacity level (point at which the tank normally discharges) and the elevation at which the filling pump starts (or filling control valve opens). This is the available fire suppression volume for elevated tanks.¶
3. Volume between the elevation that will provide 20 psig static pressure at finished grade at the base of the tank and the elevation at which the tank begins to overflow (applicable to standpipes that provide pressure by gravity). This is the nominal capacity for standpipes.¶
4. Volume between the elevation that will provide 20 psig static pressure at finished grade at the base of the tank and the elevation at which the filling pump starts (or the filling control valve opens). This is the available fire suppression volume for standpipes.¶
5. Volume between the elevation at which the withdrawal pumps shut down because of low level and the elevation at which the reservoir begins to overflow (applicable to reservoirs/tanks with withdrawal pumps). This is the nominal capacity for reservoirs.¶
6. Volume between the elevation at which the withdrawal pumps shut down because of low level and the elevation at which the filling pump starts (or the filling control valve opens). This is the fire suppression volume for reservoirs.

Deleted: Volume between the elevation at which the filling pump starts (or the filling control valve opens) and the elevation at which the filling pump stops (or the filling control valve closes). This is the turnover volume for tanks/reservoirs used to assess filling pump run lengths and heat loss/ice formation calculations.¶
8. In addition to the above volume information, the engineer shall submit a table or graph as part of the as-built plans that shows tank volume from actual tank bottom to the overflow in increments no greater than one foot elevation change. The basis for this table or graph shall be identified and geometric calculatio ... [2]

Deleted: tank/reservoir

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consideration shall be given to preventing the water in wash water tanks from freezing. Stand-by backwashing facilities shall be provided to allow the tank to be removed from service for maintenance.

7.2.2. Clearwells.

Clearwells are finished water storage facilities that are part of a treatment plant, and shall meet all of the applicable requirements for finished water storage facilities. They are used to provide disinfection contact time and as such are the last stage of treatment. In addition, clearwells may be used to provide filter wash water storage and pumped storage to help meet distribution system demands. Clearwells should be provided for surface water treatment plants. Clearwells shall be designed and constructed as part of the overall design of plant and distribution facilities to provide adequate disinfection, adequate backwash volume, and adequate distribution flow and pressure.

a. A suitable vent(s) and overflow(s) shall be provided. To prevent corrosion and damage to the plant, clearwells under the filters shall vent to the outside.

b. Disinfectant contact time shall meet requirements for inactivation of the appropriate pathogenic organism depending on whether the system source is groundwater, groundwater under the direct influence of surface water, or surface water. Detention time for disinfection is provided by the volume of water below the lowest shut off level of the clearwell. Devices shall be installed to prevent water levels from being reduced below the minimum required for disinfection. Special consideration shall be given to design of influent and effluent facilities and baffling to prevent short-circuiting.

c. Clearwell storage should be sized in conjunction with distribution system storage to allow constant rate plant operation without intermittent shutdowns. A minimum of two clear well compartments shall be provided. Each clearwell compartment shall be designed to allow it to be removed from service for maintenance while the remaining compartment continues to receive water and deliver it to the system. Access hatches shall be provided for each compartment. When clearwells are used to provide filter wash water the volume required for backwash shall be added to volumes required for equalization and disinfection contact time.

d. Clearwell storage should be sized to allow the flexibility of one, two, or three eighth-hours shifts per day operation.

e. Clearwell storage shall be piped and baffled to provide at least superior detention time characteristics with specific consideration given to influent and effluent distribution.

f. Provisions for clearwell draining shall be provided, including, but not limited to, sloped floors and sumps

Deleted: of the January 1992 Missouri Department of Natural Resources, Public Drinking Water Program Guidance Manual for Surface Water System Treatment Requirements and 10 CSR 60-4.055 Disinfection Requirements. Detention time for disinfection shall be determined using the lowest operating level in the clearwell. Special consideration shall be given to design of influent and effluent facilities and baffling to prevent short-circuiting.

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7.2.3. Receiving Basins and Pump Wet Wells

Receiving basins and pump wet wells for finished water shall be designed as finished water storage structures.

7.2.4. Finished Water Adjacent to Unsafe Water

Finished water must not be stored or conveyed into a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

7.3. Distribution Storage

These requirements are in addition to the applicable requirements listed in subsections 7.0. and 7.1.

7.3.1. Minimum PSIG at Normal Ground Elevation

Distribution storage shall be designed and constructed in conjunction with production facilities, pumping facilities, and distribution mains to provide a minimum of 35 psig pressure at the normal ground elevation at every point of the distribution system during all conditions of design flow. Normal operating conditions include extended drought usage and diurnal peak flow.

7.3.2. Working Pressure PSIG at Normal Ground Elevation

Distribution storage should be designed and constructed in conjunction with production facilities, pumping facilities, and distribution mains to provide a working pressure of 60 to 80 psig at the normal ground elevation at every point in the distribution system during all normal operating conditions except fire flow.

a. Areas with significant elevation differences should be divided into multiple pressure zones so that each zone has pressure between 35 and 100 psig.

Deleted: of more than 150 feet

b. Multiple pressure zone systems should have separate storage facilities for each zone and should be equipped so that water can be transferred between zones with pump stations and pressure control valves.

c. Each public water system shall be designed to maintain normal system pressures and flows with any storage facility out of service for maintenance or should have at least two storage tanks or reservoirs so that removing a tank or reservoir for maintenance will not disrupt distribution system pressure.

d. Where static pressures exceed 100 psig, pressure reducing devices should be provided in the mains or at the individual customer services.

e. The maximum variation between high and low levels in storage structures providing gravity pressure to the distribution system should not exceed 30 feet.

7.3.3. Distribution Storage Controls

Distribution storage facilities shall be equipped with adequate controls to maintain levels in the tanks/reservoirs.

a. Level indicating devices should be located at a central location.

b. Pumps should be controlled from tank levels with the signal transmitted by telemetry equipment when any appreciable head loss occurs in the distribution system between the pump and the storage structure. Pressure control valves (usually installed on the discharge line and pump to waste line with a control system that opens and closes these valves simultaneous to control pressure surge/water hammer) should be installed on pumps when pumps and storage facilities are not adjacent. Variable speed pumps and soft-start/soft-stop equipment may be acceptable alternatives to control valves. Where large elevation differences exist between the pumps and the storage facilities, a pressure control valve may be justified as a failsafe device in the event of

Deleted: telemetering

power outages in addition to variable speed pumps or soft-start/soft-stop equipment

c. Overflow and low level warnings or alarms should be located at places in the community where these will be under responsible surveillance 24 hours per day.

7.4. Hydropneumatic Storage

The most common applications are to maintain delivery of water within a selected pressure range while minimizing pump cycling, or to act as buffer tanks to absorb water hammer shocks in large capacity pumping systems. The two basic types of pressure tanks are conventional tanks and captive air tanks. Conventional tanks are those which allow air-water contact. Captive air tanks, often called bladder tanks have a membrane separating the air from the water phase.

7.4.1 Hydropneumatic Tank Design and Installation

a. Hydropneumatic tanks shall be certified for drinking water use under the latest version of ANSI/NSF Standard 61.

b. Large hydropneumatic tanks with a gross volume larger than 120 gallons shall be designed and constructed in accordance with the latest ASME Boiler and Pressure Vessel Code as published by the American Society of Mechanical Engineers.

c. Hydropneumatic tanks with a gross volume of 120 gallons or less shall meet the latest ANSI / WSC pressure storage tank standard for Pressure Water Storage Tanks as published by the Water Systems Council.

d. Hydropneumatic tanks shall be individually connected to the supply line to the distribution system to improve circulation to individual tanks.

e. Piping connecting tanks shall have sufficient valves and bypass lines to allow each individual tank to be taken offline, drained, repaired, painted, or replaced without causing loss of pressure in the distribution system.

f. Proper protection shall be given to metal surfaces of hydropneumatic tanks

   1. Interior coatings shall be certified for drinking water use under the latest ANSI/NSF Standard 61.
   2. Tanks constructed of steel or other metal subject to corrosion shall have both interior and exterior surfaces painted.
   3. Tanks constructed of corrosion resistant metals shall not be required to be painted. Corrosion resistant metals shall be chosen to resist corrosion from all naturally occurring chemicals in the water stored, all chemicals added as part of water treatment including chlorine and other disinfectants and the natural atmosphere. Tanks constructed of corrosion resistant metals shall be certified for drinking water use under the latest ANSI/NSF Standard 61.
   4. Hydropneumatic tanks 500 gallons or greater in size shall have interiors that are either epoxy or glass coated.

g. Hydropneumatic tanks 500 gallons or greater in size and all tanks used for disinfection contact time shall have separate inlet and outlet lines to provide positive flow through the tanks. Hydropneumatic tanks that do not have separate inlet and outlet lines do not provide disinfection detention time.

h. Hydropneumatic tanks with gross volume less than 500 gallons per tank shall be designed and constructed with the following appurtenances and features:

1. Each tank shall be completely housed in a heated building. Tanks shall not be buried or installed in direct contact with the ground to prevent freezing;
2. Each tank shall be equipped with a Schrader valve to allow air to be added to the tank and to check air pressure.
3. Tanks shall be equipped with automatic controls to control pressure/water level in the tanks.
4. A means to manage the volume and pressure of air in the air cushion of pressure tanks shall be provided but this may be done manually with portable equipment.
5. There shall be at least one pressure gage in the tank manifold.
6. Sufficient space shall be provided around the tanks to be accessible to maintenance.

Deleted: ~~2. The piping connecting tanks shall have sufficient valves and bypass lines to allow each individual tank to be taken offline, drained, repaired, painted, or replaced without causing loss of pressure in the distribution system;¶~~

7.4.2 Sizing Hydropneumatic Tanks

a. Hydropneumatic storage (conventional tanks or bladder tanks) shall not be used as the only storage facilities for community public water systems serving more than 50 connections or living units.

b. Hydropneumatic tanks used as the only storage for small community water supplies shall have minimum usable volume of 6.25 gallons per person served. This is equivalent to 35 gallons gross volume per person served when the pressure range is 40 to 60 psig and the water seal is 1/3 of the total volume for a pressure tank.

c. Hydropneumatic tanks used in conjunction with other storage and booster pumps shall have sufficient storage to control the minimum pump run times to meet the maximum cycle times per hour recommended by the pump manufacturer for the largest supplying pump. The length of minimum run time varies with the size, speed, and type of the pump motor and whether the pump is single or three-phase. The minimum run time increases as the size of the motor increases and the number of on/off cycles per hour decreases.

Deleted: ~~pump cycle times to meet the minimum cycle time recommended by the pump manufacturer for the largest supplying pump.~~

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d. Hydropneumatic tanks used as the only storage for non-community public water supplies shall have pump and usable storage size based on the number and type of plumbing fixtures served and the estimated cycle time for the largest supplying pump.

e. Multiple tanks may be used to achieve the total design volume needed.

f. Conventional tanks that provide disinfection contact time shall be designed to meet requirements for inactivation of the appropriate pathogenic organism depending on whether the system source is groundwater, groundwater under the direct influence of surface water or surface water. Detention time for disinfection is provided by the useable volume of water in the tank times a baffle factor depending on how the influent and effluent lines are piped. Guidance is provided by the January 1992 Missouri Department of Natural Resources, Public Drinking Water Program Guidance Manual for Surface Water System Treatment

Requirements, the Missouri Guidance Manual for Inactivation of Viruses in Groundwater, and 10 CSR 60-4.055 Disinfection Requirements.

g. Conventional tanks with a common inlet and outlet will not be given any credit for chlorine contact time.

7.4.3 Usable Volume

Deleted: above the normal ground surface andTanks shall not be buried or installed in direct contact with the groundMultiple tanks may be used to achieve the total design volume needed.¶

The portion of the tank volume that can be withdrawn between pumping cycles will be referred to hereafter as usable volume. This is sometimes referred to as the drawdown volume or storage capacity. To determine the usable volume in any type of hydropneumatic tank Boyle's Law must be used to determine the Acceptance or Drawdown Factors over the pressure range (cut-in to cut-out pressure) over which the tank is set to operate. The following table provides Drawdown Factors for common pressure ranges.

Table 8 – Acceptance or Drawdown Factors

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Maximum System Pressure (cut-out pressure) psig	Minimum System Pressure (cut-in pressure) psig						
	20	**25**	**30**	**35**	**40**	**45**	**50**
30	0.22	0.11					
35	0.30	0.20	0.10				
40	0.37	0.27	0.18	0.09			
45	0.42	0.34	0.25	0.17	0.08		
50	0.46	0.39	0.31	0.23	0.15	0.08	
55	0.50	0.43	0.36	0.29	0.22	0.14	0.07
60	0.54	0.47	0.40	0.33	0.27	0.20	0.13
65	0.56	0.50	0.44	0.38	0.31	0.25	0.19
70	0.59	0.53	0.47	0.41	0.35	0.30	0.24

The usable volume is the drawdown factor for the tank pressure range times the gross volume of the tank. For example an 80 gallon tank operates over a range of 40 to 60 psig which has a drawdown factor of 0.27. Multiplying 80 gallons by the 0.27 Acceptance Factor gives a usable volume of 21.6 gallons.

7.4.4. Conventional pressure tanks

a. Conventional tanks shall have a water sight glass, a pressure gage, a mechanical means of adding air, a means to adjust the air to water ratio and a pressure blow-off for excess pressure.

b. Conventional tanks shall be equipped with automatic controls to control pressure/water level in the tanks. A means to manage the volume and pressure of air in the air cushion of pressure tanks shall be provided but this may be done manually with portable equipment.

c. There shall be at least one pressure gage in the tank manifold.

d. Conventional tanks with gross volume of 500 gallons or more shall also be designed and constructed with the following appurtenances and features:

1. Each tank shall have at least one manway with minimum diameter 24-inch clear opening for circular manways. Additional manways should be provided on larger tanks as needed for access and ventilation during painting;
2. Each tank shall have a drain that shall discharge above the normal ground surface with no direct connection to a sewer or storm drain;
3. Each tank shall have adequate automatic controls to manage both the water level in the tank and the pressure of the air cushion;
4. Each tank shall be sufficiently housed to protect all appurtenances and the tank from freezing; and
5. Each tank shall be located above the normal ground surface. Tanks shall not be buried or installed in contact with the ground to protect from freezing.

Deleted: ~~18 inches by 22 inches minimum dimensions for elliptical manways.~~

Deleted: ~~Design shall be based on a 100-year return frequency extended low temperature period and average wind velocity.~~

Deleted: **<#>7.4. Hydropneumatic Storage¶**
7.4.1. Hydropneumatic storage (pressure tanks or bladder tanks) shall not be used as the only storage facilities for community public water systems serving more than 50 connections. ¶
7.4.2.Pressure tanks shall be designed and operated so that that the minimum water volume is no less than one-third (1/3) of the total volume.

Deleted: functions as a permanent water seal.¶
7.4.3. Boyle's Law shall be used to design the volume of the gas phase of pressure tanks and bladder tanks.¶
¶
Boyle's Law: $P_1V_1 = P_2V_2$ ¶
¶
Where P is absolute pressure and V is volume. ¶
¶
For units of pounds per square inc ... [3]

Deleted: For commonly used pressure ranges (pump on to pump off) and 1/3 total volume of pressure tanks used at water seal, the following table (ba ... [4]

Deleted: or bladder tanks

Deleted: used as the only storage for small community water supplies shall have a minimum

Deleted: usable

Deleted: gross volume of 35 gallons per person served

Deleted: 6.25 gallons per person served(Note this is equivalent to 35 gallons gross volume per person served when the pressure range is 40 to 6 ... [5]

Deleted: Bladder tanks used as the only storage for small community water supplies shall have a minimum volume based upon the above table.¶ ... [6]

Deleted: 7.4.2 Hydropneumatic storage (pressure tanks or bladder tanks) shall not be used as the only storage facilities for community public wa ... [7]

Deleted: 7.4.3 Pressure tanks or bladder tanks used as the only storage for small community water supplies shall have a minimum usable volume of ... [8]

Deleted: **<#>7.5. Fire Flow Information¶**
7.5.1. Standard Fire Flow with Corresponding Fire Durations.¶ ... [9]

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Chapter 8 - Distribution Systems

8.0. Materials.

8.0.1. Standards and materials selection.

Pipes and fittings shall conform to the latest edition of the AWWA, ASTM, Plastic Pipe Institute (PPI), or UniBell Plastic Pipe Association standards or recommendations. All pipes, fittings, valves, and fire hydrants shall conform to the latest standards issued by the AWWA and, where applicable, shall be certified by NSF or Underwriters Laboratories for use in drinking water. Special attention shall be given to selecting pipe materials that will protect against both internal and external pipe corrosion.

a. Polyvinyl Chloride (PVC) pipes that are less than three inches in diameter shall be at least Class 200 and conform to a Standard Dimension Ratio (SDR) 21.

b. PVC pipes three inches through 12 inches in diameter shall be no less than Class 160 and conform to SDR-26. Pipe classified for higher pressures should be used where appropriate.

c. Plastic pipe shall meet ANSI/AWWA Standard C900 or C909 for polyvinyl chloride pipe; ANSI/AWWA Standard C901, C905 or C906 for polyethylene or ANSI/AWWA Standard C950 for fiberglass pipe.

d. Pipes, fittings, and appurtenances containing more than 8 percent lead shall not be used.

e. Fittings shall have at least the same pressure rating as the pipe.

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8.0.2 High Density Polyethylene (HDPE) Pipe.

HDPE pipe is mainly used in horizontal directionally bored pipe installations. It has proven acceptable for river and road crossings and similar installations. It is being used in some pipe bursting, splitting, and other trenchless operations. The unique properties of HDPE pipe present special design considerations that must be addressed when proposing its installation. The following requirements must be met when proposing the installation of HDPE pipe.

a. Polyethylene's response to temperature change is significant and unique when compared to other traditional pipe materials. Anchored or end restrained pipe such as connections between HDPE pipe and other types of pipe will develop longitudinal stresses or thrust instead of undergoing a change in length. The resulting stress or thrust loads can be significant and the restraining structures must be designed to resist the anticipated loads. The Plastic Pipe Institute technical guidelines for connecting HDPE pipe to other types of pipe shall be used.

b. Poisson effects on HDPE pipe can be significant because Poisson forces are transmitted length to length through the entire HDPE pipe string. HDPE pipe designs must address this issue. Joints or mechanical connections that are inline with HDPE pipe shall be either restrained or otherwise protected against pullout disjointing in accordance with Plastic Pipe Institute guidelines. Snaking pipe in a trench is not effective and is not recommended.

c. Methods to control frequent sudden pressure surges or flow changes shall be provided to prevent fatigue failures of the pipe.

d. Heat fusion joining by butt fusion using certified methods is the preferred method of connecting lengths of HDPE pipe and of installing fittings in HDPE pipe. Any mechanical methods of joining HDPE pipe or of installing fittings shall be specifically designed for use with HDPE pipe.

e. Extrusion or hot gas welding are not substitutes for butt, saddle, or socket fusion and are not to be used to join or repair HDPE pressure pipe or fittings.

f. Scrapes or gouges cannot be repaired with extrusion or hot air welding. The damaged sections shall be removed and replaced. Broken or damaged fittings cannot be repaired with extrusion or hot air welding. They must be removed and replaced.

g. High density polyethylene plastic (HDPE) pipe four inches in diameter or larger shall have a standard dimension ratio (SDR) no greater than 11. Pipes smaller than four inches in diameter and pipe of any size where normal water pressures are 100 psig or more shall be no greater than SDR – 9.

h. Because of thermal and Poisson forces and other unique properties of HDPE pipe, conventional service saddles and tapping tees are not acceptable for use with HDPE pipe. Only mechanical strap-on saddles that are certified by the manufacturer for use on HDPE pipe shall be approved. Electrofusion, saddle, or socket fusion saddles and tapping tees shall meet the Plastic Pipe Institute's recommendations for buried HDPE pressure pipe.

i. Stainless steel pipe stiffeners are required for use with mechanical strap-on saddles or mechanical joint connections.

j. Valves shall be installed using butt fusion joining or by mechanical flanged or restrained joints.

8.0.3 Permeation of pipe walls.

In areas that are contaminated with organic chemicals, permeation of organic chemicals into the water system shall be prevented by using non-permeable materials for all portions of the water system including pipe, fittings, service connections, and hydrant leads.

8.0.4. Used materials.

Only water mains that have been used previously for conveying potable water may be reused, and must meet the above standards and have been practically restored to their original condition.

8.0.5. Joints.

Packing and jointing materials used in the joints of pipe shall conform to the latest edition of the AWWA standards. Pipe having mechanical joints or slip-on joints with rubber gaskets is preferred.

8.0.6. Tracer Wire or Tape.

All non-metal pipes shall be installed with tracer wire or tape to facilitate future location of the pipe. However, tracer wire or tape is not a substitute for accurate as-built plans or individual fixture records on each extension or modification of a system. The following requirements shall be met when designing tracer wire or tape systems.

a. Tracer wire shall be designed specifically for detecting buried utilities with a gasoline and oil resistant plastic jacket that is designed specifically for buried use.
b. Tracer wire or tape shall be chosen appropriate to the expected life of the utility.
c. The wire or tape shall be installed in such a manner as to be able to properly trace all water mains without loss or deterioration of signal or without the transmitted signal migrating off the tracer.
d. Tracer wire or tape shall not be wrapped around the pipe in a spiral as this is a source of signal degradation and adds physical stress to the tracer.
e. The wire or tape shall be placed on top and along the length of the pipe and fastened to the pipe at least every 8 to 12 feet to secure it in place when the trench is backfilled.
f. Tracer wire or tape shall be located directly above and within 6 inches of the non-metallic pipe.
g. If it is necessary to join tracer wire below ground, the wire shall be joined in a permanent bond (braising, cad welding or equivalent) and the joined area insulated and rendered watertight in order to prevent corrosion.
h. Tracer tape shall not have below ground connections.
i. Tracer wire should be a minimum of 12 gauge, insulated, single-conductor copper wire or equivalent.
j. Tracer tape shall consist of a continuous metal core inseparably bonded on both sides with tough, high density, cross laminated, non-biodegradable, plastic films.
k. Exterior access shall be provided to the tracer wire or tape at close enough intervals to assure adequate transmission of signals from access point to access point..
l. Exterior access locations shall include a means of protecting the tracer wire or tape, preferably in a manufactured tracer wire box.
m. All tracer wire or tape for new utility installations shall be tested before acceptance.

8.1. Water Main Design.

8.1.1. Pressure.

All water mains shall be sized in accordance with a hydraulic analysis based on flow demands and pressure requirements. The system shall be designed to maintain a minimum pressure of 35 psi at ground level at all points in the distribution system under all conditions of design flow not including fire flow. The normal working pressure in the

Deleted: , except that the department may approve a minimum design pressure of 20 psi in areas served by rural water districts.

distribution system should be around 60 psi. Water pressure below 20 psi is a hazard to public health and a violation of Missouri Safe Drinking Water Regulation 10 CSR 60-4.080 (9).

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8.1.2. Diameter.

a. The minimum size of a water main for providing fire protection and serving fire hydrants shall be six inches in diameter. Larger mains shall be required, if necessary, to allow withdrawal of the required fire flow while maintaining the minimum residual pressure of 20 pounds per square inch throughout the distribution system.

b. For public water systems not providing fire protection, no main shall be smaller than two inches in diameter.

8.1.3. Fire Protection.

Systems that cannot provide a minimum fire flow of 250 gallons per minute for a duration of two hours are not designed to provide any fire protection. Water mains that are not designed to provide fire protection shall not have fire hydrants connected to them.

Deleted: When fire protection is to be provided, system design should be such that fire flows and facilities meet the classification criteria of the state Insurance Services Office (ISO). Water mains not designed to carry fire-flows shall not have fire hydrants connected to them

See Chapter 7.1.1. of this guide for more information on fire protection.

8.1.4. Flushing.

The ability to adequately flush all parts of the distribution system is essential in emergencies and for flushing contamination from the water system. Routine flushing is essential to maintaining a safe quality of water in the system. The following requirements shall be met when designing flushing systems.

a. Proposed projects submitted to the department for review shall include supportive documentation that shows water lines can be adequately flushed while maintaining the minimum required pressures. Each submittal shall be accompanied by a hydraulic analysis that evaluates the proposed extension at average design flows and peak flows, including flushing requirements. This analysis needs to include existing lines back to the nearest storage tank or booster pump station.

b. Flushing devices and valves shall be provided to allow every main in the distribution system to be flushed. Flushing devices should be sized to provide flows that will give a velocity of at least 2.5 feet per second in the water main being flushed.

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c. In order to provide increased reliability of service and reduce head loss, dead ends shall be minimized by making appropriate tie-ins whenever practical.

d. Where dead-end mains occur, they shall be provided with an approved flushing device.

e. No flushing device shall be directly connected to any sewer.

f. Long runs of transmission mains shall have flushing devices located at no longer than one mile intervals.

g. Flushing devices shall be sized to provide a maximum flow that does not drop system pressures below 20 PSI. Throttling valves shall be set on the leads to flushing devices to set the maximum flow of the device so that it will not drop system pressures below 20 PSI.

h. Flushing devices should be installed at low points of the water main installation, depending on flow rate and pipe profile, where sediment may accumulate.

8.2. Isolation Valves.

The ability to adequately isolate parts of the distribution system is essential in an emergency. Sufficient valves shall be provided on water mains to allow a system to be adequately flushed and so that inconvenience and sanitary hazards to customers will be minimized during repairs. The following requirements shall be met when designing system valves.

a. The weight of the valve shall not be carried by the pipe. Valves shall be provided with proper support, such as crushed stone, concrete pads or a well compacted trench bottom.

b. where water mains connect, a valve shall be installed on each branch off of the main line and one on the main line.

c. Large mains should be valved so that during an outage on a smaller line, the large main will not be affected.

d. As a rule of thumb, no more than four valves should required closing to isolate a pipe.

e. At a reducer, a valve should be placed in the smaller pipe within 20 feet of the reducer.

f. In long transmission mains with few branches, valves should be installed at intervals of no greater than one mile.

g. In municipalities, valves should be located at not more than 500 foot intervals in commercial areas and at not more than one block or 800 foot intervals in residential or other areas.

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8.3. Fire Hydrants.

8.3.1. Location and spacing.

In most communities, hydrants should be provided at each street intersection and at intermediate points between intersections to meet the classification criteria of the state ISO. Generally, hydrant spacing may range from 350 to 600 feet, depending on the area being served. Hydrants in partially built-out areas should be spaced not to exceed 500 feet of vehicle travel distance from a building. In un-built areas, fire hydrants should be spaced not more than 1500 feet apart.

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8.3.2. Valves and nozzles.

Fire hydrants should have a minimum bottom valve size of at least five inches, one 4-1/2 inch pumper nozzle, and two 2-1/2 inch nozzles.

8.3.3. Hydrant leads.

a. The hydrant lead line (the line from the main to the hydrant) shall be a minimum of six inches in diameter and contain a throttling valve which can also act as a shutoff valve. The throttling valve shall be set to the maximum flow that will not drop system pressures below 20 PSI as determined by both area hydraulic analyses and individual testing of each hydrant.

b. In submittals of plans of record to the department, the maximum allowable flow for each hydrant shall be stated.

c. Thrust restraint shall be provided for throttling valve so that the hydrant may be removed without shutting down the supply main.

d. The hydrant lead pipe should be of the same material as the supply main to prevent damage to the main in the event that the hydrant is hit during a traffic accident.

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8.3.4. Drainage.

A gravel pocket or dry well shall be provided unless the natural soils will provide adequate drainage for the hydrant barrel. Hydrant drains shall not be connected to or located within ten feet of sanitary sewers or storm drains.

8.3.5. Color Coding

All fire hydrants shall be flow tested to determine the maximum flow that each hydrant can produce without dropping the system pressures below 20 PSI. The throttling valve shall then be set at the maximum flow that will not drop system pressures below 20 PSI. Depending upon the results of the flow test, the bonnet and nozzle caps of each hydrant should be painted the appropriate color to indicate its flow class in accordance with the latest NFPA standard.

8.3.6. Installation

Installation of fire hydrants shall meet the following requirements.

a. The weight of the hydrant shall not be carried by the pipe. Hydrants, lead valves, fittings, and branch connections shall be provided with proper support, such as crushed stone, concrete pads or a well compacted trench bottom.

b. Drainage shall be provided for dry barrel hydrants. This is generally washed stone extending at least one foot on all sides of the hydrant.

c. Hydrants shall be plumb.

d. The center of a hose outlet shall be not less than 18 inches above final grade and so that the final hydrant installation is compatible with the final grade elevation.

e. As a rule, hydrants are either oriented with the pumper outlet perpendicular to the curb which faces the street, or with the pumper outlet set at a 45 degree angle to the street.

f. Hydrants shall be protected if subject to mechanical damage. The means of protection shall be arranged in a manner that will not interfere with the connection to, or operation of, hydrants.

g. A clearance space of at least three feet (3 ft.) surrounding the hydrant body shall be provided around every hydrant.
h. Utility poles, vaults, walls, plants and other landscape materials must be kept outside the hydrant's clearance space.
i. In poor load-bearing soil, special construction such as support collars may be required

8.4. Air Relief Valves; Valve, Meter and Blow-Off Chambers

8.4.1. Location.

At high points in water mains where air can accumulate, provisions shall be made to remove the air by means of manually operated hydrants or air relief valves.

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Automatic air relief valves shall not be used unless air accumulation is a continuous problem that requires automatic removal. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur. Submergence of an automatic air relief valve is a significant health hazard and a direct cross-connection with unsafe water. Automatic air relief valves shall not be installed in locations where the valve vault cannot be adequately drained to prevent flooding of the valve.

8.4.2. Piping.

The open end of an air relief pipe from automatic valves shall be extended to at least one foot above grade and terminate in a downturned position with the opening covered with an 18-mesh, corrosion resistant screen. The discharge pipe from a manually operated valve shall be capped with a threaded removable cap or plug and should be extended to the top of the pit. Vaults or wells housing automatic air relief valves shall be drained to daylight with drains sized to carry the maximum output of the air relief valve.

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8.4.3. Chamber drainage.

Chambers, pits, or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system, shall not be connected directly to any storm drain or sanitary sewer, nor shall blow-offs or air relief valves be connected directly to any sewer. Such chambers or pits shall be drained to the surface of the ground or provided with sump.

8.4.4. Vaults.

Vaults for inline pressure control valves or for large master meter connections between public water systems or to large customers serving many people such as mobile home parks, apartment complexes, nursing homes, factories, and hospitals shall meet all of the requirements detailed in Section 7.0.17 of this guide.

Remote read out equipment should be provided to allow meters to be read without entering the vault.

8.5. Installation of Mains.

8.5.1. Standards.

Specifications shall incorporate the provisions of the AWWA standards and/or manufacturer's recommended installation procedures.

8.5.2. Bedding, Embedment, and Backfill.

Bedding is the portion of the trench beneath the pipe and supporting the pipe to its spring line. Embedment is the material placed around the pipe to at least six inches above the top of the pipe. Backfill is the material placed into the trench above the embedment. Water main installation design shall meet the following requirements.

a. Trench construction, bedding, and embedment shall be appropriate for the type and size of the pipe installed.

b. Continuous, firm, stable, and uniform bedding shall be provided in the trench for all buried pipe. The bedding design shall insure that there is full support in the haunches of the pipe and be smooth and free of ridges, hollows, and lumps.

c. Bell holes should be excavated so that only the barrel of the pipe receives bearing from the trench bottom.

d. The weight of metallic fittings shall not be supported by the pipe. Metallic fittings shall be provided with proper support, such as crushed stone, concrete pads or a well compacted trench bottom.

e. Rocks and hard objects larger than one inch diameter found in the trench shall be removed at least four inches below and on each side of the pipe and the trench bottom should be filled with 4 to 6 inches of tamped bedding material.

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f. When an unstable sub-grade condition which will provide inadequate pipe support is encountered, an alternative foundation shall be provided such as over digging and backfilling with tamped granular material.

g. The trench shall be kept free from water during pipe installation until the pipe has been installed, embedded and backfilled.

h. If the trench passes over another pipe or previous excavation, the trench bottom shall be filled with granular material and compacted.

i. Blocking shall not be used to change pipe grade or to intermittently support pipe across excavated sections.

j. All bedding and embedment material shall be free from cinders, ashes, refuse, vegetable or organic material, boulders, rocks or stones.

k. Embedment material should be tamped in layers around the pipe, and to a sufficient height above the pipe that the pipe is adequately supported, stabilized, and protected. Shaped beddings perform essentially as well as full-contact embedment with select granular soil and are considered equal to full contact bedding.

l. Bedding normally consists of free flowing material such as gravel, sand, silty sand, or clayey sand. If this material is not used, a chipper should be used on the trencher to prepare the soil removed from the trench as embedment and backfill.

m. Embedment material diameter for plastic pipe shall be no greater than ½ inch for 4-inch diameter pipe, ¾ inch for 6 and 8 inch diameter pipes, and 1-inch for pipe diameters from 10 inches and greater.

n. Sand or other fine non-acidic granular material shall be used for pipe bedding, embedment and backfill in high traffic areas and under paved roads.

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o. Backfill may consist of the excavated material, provided it is free from unsuitable matter such as large lumps of clay, frozen soil, organic material, boulders, or stones larger than 8 inches, or construction debris.

p. Width of trenches shall be at least four inches larger than the pipe's diameter. The minimum clear width of a trench should be the pipe outside diameter plus twelve inches. Where embedment compaction is required, the trench width shall be wide enough to accommodate the compaction equipment.

8.5.3. Cover.

All water mains shall be covered with at least 42 inches of earth or other insulation to prevent freezing. Lesser cover depth may be accepted in certain areas as approved by the department.

8.5.4. Thrust Restraint.

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Properly installed reaction blocking or thrust restraint shall be provided for each dead end, valve, hydrant, flushing device, bend, T-connection, reducer, wye, cross, or other fitting. Reaction blocking or thrust restraint shall be designed to withstand the specific forces expected in the particular construction conditions. Wooden or steel posts or blocking made of wood or other biodegradable material shall not be used. Pre-cast concrete blocks should not be used. All restraining rods, bolts, and nuts should be stainless steel.

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8.5.5. Pressure and leakage testing.

All types of installed pipe shall be pressure tested and leakage tested in accordance with the latest edition of AWWA Standard .

8.5.6. Disinfection.

All new, cleaned, or repaired water mains shall be disinfected in accordance with the latest edition of the AWWA Standard. The specifications shall include detailed procedures for the adequate flushing, disinfection, and microbiological testing of all water mains.

8.6. Separation of Water Mains, Sanitary Sewers and Combined Sewers

When buried water mains are in close proximity to non-potable pipelines, the water mains are vulnerable to contamination that can pose a risk of waterborne disease outbreaks. For example, sewers (sanitary sewer mains and sewage force mains) frequently leak and saturate the surrounding soil with sewage due to structural failure, improperly constructed joints, and/or subsidence or upheaval of the soil encasing the sewer. If a nearby water main is depressurized and no or negative pressure occurs, that situation is a public health hazard. The public health hazard is compounded if an existing sewer is broken during the installation or repair of the water main. Further, failure of a water main in close proximity to other pipelines may disturb their bedding and cause them to fail. To protect the public health, the following requirements shall be met. These requirements apply to horizontally directionally drilled pipe or pipe installed through other trenchless methods as well as pipe installed by conventional open cut methods.

8.6.1. General.

The following factors should be considered in providing adequate separation:

a. Materials and type of joints for water and sewer pipes;
b. Soil conditions;
c. Service and branch connections into the water main and sewer line;
d. Compensating variations in the horizontal and vertical separations;
e. Space for repair and alterations of water and sewer pipes; and
f. Off-setting of water mains around manholes.

8.6.2. Parallel installation.

The water main shall be located at least ten feet horizontally from any existing or proposed line carrying non-potable fluids such as, but not limited to drains, storm sewers, sanitary sewers, combined sewers, sewer service connections, and process waste or product lines. The distance shall be measured edge to edge.

In cases where it is not practical to maintain a ten-foot separation, the department may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the water main closer to a non-potable fluid line, provided that the water main is laid in a separate trench located as far away from the non-potable line as feasible and meets other specific construction requirements. Locating a water main on an undisturbed earth shelf located on one side of the non-potable line is not recommended and requires justification by the engineer and specific case-by-case approval of the department. In either case, an elevation shall be maintained such that the bottom of the water main is at least 18 inches above the top of the non-potable line while meeting minimum cover requirements.

In areas where the recommended separations cannot be obtained, either the waterline or the non-potable line shall be constructed of mechanical or manufactured restrained joint pipe, fusion welded pipe, or cased in a continuous casing. Casing pipe must be a material that is approved for use as water main. Conventional poured concrete is not an acceptable encasement.

8.6.3. Crossings.

Water mains crossing sewers, or any other lines carrying non-potable fluids shall be laid to provide a minimum vertical clear distance of 18 inches between the outside of the water main and the outside of the non-potable pipeline. This shall be the case where the water main is either above or below the non-potable pipeline. 18-inch separation is a structural protection measure to prevent the sewer or water main from settling and

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breaking the other pipe. At crossings, the full length of water pipe shall be located so both joints will be as far from the non-potable pipeline as possible but in no case less than ten feet. In areas where the recommended separations cannot be obtained either the waterline or the non-potable pipeline shall be constructed of mechanical or manufactured restrained joint pipe, fusion welded pipe, or cased in a continuous casing that extends no less than ten feet on both sides of the crossing. Special structural support for the water and sewer pipes may be required. Casing pipe must be a material that is approved for use as water main. Conventional poured concrete is not an acceptable encasement.

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8.6.4. Exception.

Any variance from the specified separation distances in paragraphs 8.6.2.and 8.6.3. must be submitted to the department for approval.

8.6.5. Force mains.

There shall be at least a ten-foot horizontal separation between water mains and sanitary sewer force mains or other force mains carrying non-potable fluids and they shall be in separate trenches. In areas where the recommended separations cannot be obtained, either the waterline or the non-potable line shall be constructed of mechanical joint pipe or cased in a continuous casing. Where possible, the waterline shall also be at such an elevation that the bottom of the water main is at least 18 inches above the top of the non-potable line. Casing pipe must be a material that is approved for use as water main. Conventional poured concrete is not an acceptable encasement.

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8.6.6. Sewer manholes.

No waterline shall be located closer than ten feet to any part of a sanitary or combined sewer manhole.

8.6.7. Disposal facilities.

No water main shall be located closer than 25 feet to any wastewater disposal facility, agricultural waste disposal facility, or landfill. Water mains shall be separated by a minimum of 25 feet from septic tanks and wastewater disposal areas such as cesspools, subsurface disposal fields, pit privies, land application fields, and seepage beds.

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8.7. Surface Water Crossings.

Surface water crossings present special problems, whether over or under water. The department should be consulted before final plans are prepared. Special detail drawings shall be submitted that are scaled and dimensioned to show the approximate bottom of the stream, the approximate elevation of the low and high-water levels, and other topographic features. Mechanical, restrained, or fusion welded joint pipe shall be required in waterways and wet weather streams.

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8.7.1. Above-water crossings.

The pipe shall be adequately supported and anchored, protected from damage and freezing and accessible for repair or replacement.

8.7.2. Underwater crossings.

a. Flowing streams and water body crossings five hundred feet or less in length shall have a minimum cover of four feet over the pipe. When crossing water courses are greater than 15 feet in width, the following shall be provided:

   1. The pipe shall be of special construction, having flexible watertight joints. Steel or ductile iron ball-joint river pipe shall be used for open cut crossings. Mechanical or restrained joint or fusion welded pipe may be used for open cut crossings, provided it is encased in a welded steel casing. Mechanical or restrained joint or fusion weld pipe shall be used for bored crossings.
   2. Adequate support and anchorage shall be provided on both sides of the stream.
   3. Valves shall be provided at both ends of water crossings so that the section can be isolated for testing or repair; the valves shall be easily accessible and should not be subject to flooding.
   4. The valve closest to the supply source shall be in an accessible location and installed in a vault, manhole, or meter pit sized to allow the installation of leak detection equipment.
   5. Permanent taps shall be provided on each side of the valve within the manhole, vault, or meter pit to allow insertion of a small meter to determine leakage and for sampling purposes.
   6. Bank erosion is a major cause of stream crossing failures, and erosion protection measures such as rip rap have limited success. Stream movement and the history of bank erosion must be considered when choosing the length that the crossing pipe or casing shall extend beyond the upper edge of the stream channel. The stream crossing pipe or casing shall extend at least 15 feet beyond the upper edge of the stream channel on each side of the stream.
   7. Large river crossings such as those crossing the Missouri or Mississippi River require specialized design and shall be considered on a case-by-case basis.

b. For lake, water body, and flood plain crossings greater than five hundred feet in length, the design shall consider the ability to access and repair or replace the pipe in these crossings. Consideration shall also be given to the ability to continue service to areas served by the crossing in the event of a submerged leak or pipe break.

   1. Submerged portions of pipe crossing proposed lakes shall not be buried when the submerged pipe is greater than five hundred feet in length except for the transition from water to land.
   2. Steel or ductile iron ball-joint river pipe or fusion welded pipe shall be used under water during normal flow conditions. Mechanical, restrained joint, or

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Deleted: ; and the valve closest to the supply source shall be in an accessible location fusion welded pipe shall be used in flood plains.

3. Underwater installations shall be tested for leaks prior to installation.
4. Valves above the high water level shall be provided at both ends of water crossings so that the section can be isolated for testing or repair.
5. The valve closest to the supply source shall be in an accessible location and installed in a vault, manhole, or meter pit sized to allow the installation of leak detection equipment.
6. Permanent taps shall be provided on each side of the valve within the manhole, vault, or meter pit to allow insertion of a small meter to determine leakage and for sampling purposes.

c. Intermittent flowing streams.

1. Restrained joint or thermal welded pipe shall be used for all stream crossings;
2. The pipe shall extend at least 15 feet beyond the upper edge of the stream channel on each side of the stream.
3. Adequate support and anchorage shall be provided on both sides of the waterway.

8.8. Backflow Prevention.

The water system must be protected from introduction of contaminants by backflow in accordance with 10 CSR 60-11.010 Prevention of Backflow.

8.9. Water Services and Plumbing.

8.9.1. Plumbing.

a. Water services and plumbing shall conform to the applicable local plumbing codes. Pipes and pipe fittings containing more than 8% lead shall not be used.
b. Solders and flux containing more than 0.2% lead shall not be used.
c. Plumbing fittings and fixtures not in compliance with standards established in accordance 42 U.S.C. 300g-6(e) shall not be used.

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8.9.2. Booster pumps.

See Chapter 6 of this document.

8.10. Service Meters.

Each service connection shall be individually metered.

8.11. Water Loading Stations.

Water loading stations present special problems since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels being filled, the following requirements shall be met in the design of water loading stations.

8.11.1. Backflow.

An appropriate backflow prevention arrangement shall be incorporated in the piping so there is no backflow to the public water supply.

8.11.2. Filling device.

A filling device shall be used so the hose does not extend into the water vessel to prevent contaminants being transferred from a hauling vessel to others subsequently using the station.

8.11.3. Hose length.

Hoses shall be short enough that they do not contact the ground or any constructed platform. Hanging brackets or rope and pulley hoist is acceptable.

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Adsorption by granular activated carbon. Consideration should be given to:

1. Determining the filter isotherm for the particular contaminant to be removed, and the minimum contact time with the carbon bed that is necessary for removing the contaminant;
2. Using contact units rather than replacing portions of existing filter media;
3. Series and parallel flow piping configurations to minimize the effect of breakthrough without reliance on continuous monitoring;
4. Providing at least two units. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved rate. Where more than two units are provided, the contactors shall be capable of meeting the design capacity at the approved rate with one (largest) unit out of service;
5. Using virgin carbon. Although reactivated carbon may present an economic advantage at large water treatment plants, such an alternative may be pursued only with the preliminary endorsement of the department. If regenerated carbon is accepted, only carbon previously used for potable water treatment can be used for this purpose. Transportation and regeneration facilities must not have been used for carbon put to any other use; and
6. Acceptable means of spent carbon disposal, pursuant to hazardous waste management regulations in 10 CSR 25.

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Volume between the elevation at which the filling pump starts (or the filling control valve opens) and the elevation at which the filling pump stops (or the filling control valve closes). This is the turnover volume for tanks/reservoirs used to assess filling pump run lengths and heat loss/ice formation calculations.

8. In addition to the above volume information, the engineer shall submit a table or graph as part of the as-built plans that shows tank volume from actual tank bottom to the overflow in increments no greater than one foot elevation change. The basis for this table or graph shall be identified and geometric calculations shown or actual metered volumes listed.

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functions as a permanent water seal.

7.4.3. Boyle's Law shall be used to design the volume of the gas phase of pressure tanks and bladder tanks.

Boyle's L

Where P is absolute pressure and V is volume.

For units of pounds per square inch, absolute pressure is: psia = psig + 14.7

Where psia indicates absolute pressure and psig indicates gage pressure.

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For commonly used pressure ranges (pump on to pump off) and 1/3 total volume of pressure tanks used at water seal, the following table (based on Boyle's Law) may be used for design. Note that usable volume is also called drawdown volume and that bladder tanks have no permanent water seal.

Table 4 - Hydropneumatic Tank Usable Volume (% Total Tank Volume)

Tank Type		Pressure Range		
		20-40 psig	30-50 psig	40-60 psig
Pressure	Percent of total Usable volume	42.29%	46.06%	48.82%
	Permanent Ggas cushion usable volume	24.38%	20.61%	17.85%
	Minimum Water VolumePermanent water seal	33.33%	33.33%	33.33%
Bladder	Permanent Ggas cushion	63.44%	60.09%	73.23%
	Usable volume	36.56%	30.91%	26.77%

Pressure tanks

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6.25 gallons per person served(Note this is equivalent to 35 gallons gross volume per person served when the pressure range is 40 to 60 psig and the water seal is 1/3 of the total volume for a pressure tank.)

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Bladder tanks used as the only storage for small community water supplies shall have a minimum volume based upon the above table.

7.4.5. Pressure tanks or bladder tanks used in conjunction with other storage and booster pumps and those used as the only storage for noncommunity public water supplies shall have a usable volume sufficient to store at least two minutes discharge from the largest supplying pump.

7.4.6. Pressure tanks shall have separate inlet and outlet lines to provide positive flow through the tanks.

Bladd … o the supply line to the distri … dividual tanks.

7.4.8. Hydr … nking water use under the la…

7.4.9. Hydropneumatic tanks should be designed and constructed in accordance with the latest ASME Boiler and Pressure Vessel Code Section II, Part A, B, C, D, Section V, Section VIII Division I and

Section IX published by the American Society of Mechanical Engineers.

7.4.10. Pressure tanks that provide disinfection contact time shall be designed to meet requirements of the January 1992 Missouri Department of Natural Resources, Public Drinking Water Program <u>Guidance Manual For Surface Water System Treatment Requirements</u> and 10 CSR 60-4.055 Disinfection Requirements.

7.4.11. Pressure tanks shall have a water sight glass, a pressure gage, a mechanical means of adding air, a means to adjust the air to water ratio and a pressure blow off for excess pressure. Where multiple pressure tanks are manifolded to maintain identical pressure and water level, a single sight glass and single pressure blow off valve may be used.

Pressure tanks with gross volume of 1,000 gallons or more per tank shall be designed and constructed with the following appurtenances and features:

a. Each tank shall have at least one manway with minimum diameter 24-inch clear opening for circular manways or 18 inches by 22 inches minimum dimensions for elliptical manways. Additions manways should be provided on larger tanks as needed for access and ventilation during painting;
b. Each tank shall have a water sight glass, a pressure gage, a mechanical means of adding air, a pressure blow off for excess air, and a drain. The drain shall discharge above the normal ground surface with no direct connection to a sewer or storm drain;
c. The piping connected to each tank shall be equipped with sufficient valves and bypass lines to allow the tank to be taken offline, drained, cleaned, repaired and painted without causing loss of pressure in the distribution system;
d. Each tank shall have adequate automatic controls to manage both the water level in the tank and the pressure of the air cushion; and
e. Each tank shall be sufficiently housed to protect all appurtenances and the tank from freezing. Each tank shall be located above the normal ground surface. Design shall be based on a 100-year return frequency extended low temperature period and average wind velocity.

7.4.12.

Pressure tank ... s than 1,000 gallons per ta ... the following appu ...

a. Each tank shall be above the normal ground surface and completely housed in a heated building to prevent freezing;
b. The piping connecting tanks shall have sufficient valves and bypass lines to allow each individual tank to be taken offline,

drained, repaired, painted, or replaced without causing loss of pressure in the distribution system;

c. The tanks shall be equipped with automatic controls to control pressure/water level in the tanks. A means to manage the volume and pressure of air in the air cushion of pressure tanks shall be provided but this may be done manually with portable equipment. There shall be at least one pressure gage in the tank manifold; and

d. Multiple tanks may be used to achieve the total design volume needed.

7.4.13. Proper protection shall be given to metal surfaces of pressure tanks

a. Tanks constructed of steel or other metal subject to corrosion shall have both interior and exterior surfaces painted.
   1. Exterior paint should contain less than 100 milligrams of lead per kilogram of dried paint to prevent removed paint from being classified as a hazardous waste.
   2. Interior paint shall be certified for drinking water use under the latest ANSI/NSF Standard 61.

b. Tanks constructed of corrosion resistant metals shall not be required to be painted. Corrosion resistant metals shall be chosen to resist corrosion from all naturally occurring chemicals in the water stored, all chemicals added as part of water treatment including chlorine and other disinfectants and the natural atmosphere including current and expected future air pollutants in the area.

7.4. Hydropneumatic Storage

Hydropneumatic tanks do not provide true water storage, but are more accurately well control devices.

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7.4.2 Hydropneumatic storage (pressure tanks or bladder tanks) shall not be used as the only storage facilities for community public water systems serving more than 50 connections or living units.

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7.4.3 Pressure tanks or bladder tanks used as the only storage for small community water supplies sh[illegible] 5 gallons per person served. (Note th[illegible] per person served when the pressu[illegible] is 1/3 of the total volume for a pressure tank.)

7.4.4. Pressure tanks or bladder tanks used in conjunction with other storage and booster pumps and those used as the only storage for noncommunity public water supplies shall have a usable volume sufficient to store at least two minutes discharge from the largest supplying pump.

7.4.6. Pressure tanks shall have separate inlet and outlet lines to provide positive flow through the tanks.

7.4.7. Bladder tanks shall be individually connected to the supply line to the distribution system to improve circulation to individual tanks.

7.4.8. Hydropnuematic tanks shall be certified for drinking water use under the latest version of ANSI/NSF Standard 61.

7.4.9. Hydropneumatic tanks should be designed and constructed in accordance with the latest ASME Boiler and Pressure Vessel Code Section II, Part A, B, C, D, Section V, Section VIII Division I and Section IX published by the American Society of Mechanical Engineers.

Pressure tanks that provide disinfection contact time shall be designed to meet requirements of the January 1992 Missouri Department of Natural Resources, Public Drinking Water Program <u>Guidance Manual For Surface Water System Treatment Requirements</u> and 10 CSR 60-4.055 Disinfection Requirements.

Pressure tanks shall have a water sight glass, a pressure gage, a mechanical means of adding air, a means to adjust the air to water ratio and a pressure blow off for excess pressure. Where multiple pressure tanks are manifolded to maintain identical pressure and water level, a single sight glass and single pressure blow off valve may be used.

7.4.12. Pressure tanks with gross volume of 1,000 gallons or more per tank shall be designed and constructed with the following appurtenances and f

a. E ith minimum diameter 2 or 18 inches by 22 inches minimum dimensions for elliptical manways. Additions manways should be provided on larger tanks as needed for access and ventilation during painting;

b. Each tank shall have a drain that shall discharge above the normal ground surface with no direct connection to a sewer or storm drain;
c. The piping connected to each tank shall be equipped with sufficient valves and bypass lines to allow the tank to be taken offline, drained, cleaned, repaired and painted without causing loss of pressure in the distribution system;
d. Each tank shall have adequate automatic controls to manage both the water level in the tank and the pressure of the air cushion; and
e. Each tank shall be sufficiently housed to protect all appurtenances and the tank from freezing. Each tank shall be located above the normal ground surface. Design shall be based on a 100-year return frequency extended low temperature period and average wind velocity.

7.4.12. Pressure tanks and bladder tanks with gross volume less than 1,000 gallons per tank shall be designed and constructed with the following appurtenances and features:
a. Each tank shall be above the normal ground surface and completely housed in a heated building to prevent freezing;
b. The piping connecting tanks shall have sufficient valves and bypass lines to allow each individual tank to be taken offline, drained, repaired, painted, or replaced without causing loss of pressure in the distribution system;
c. The tanks shall be equipped with automatic controls to control pressure/water level in the tanks. A means to manage the volume and pressure of air in the air cushion of pressure tanks shall be provided but this may be done manually with portable equipment. There shall be at least one pressure gage in the tank manifold; and
d. Multiple tanks may be used to achieve the total design volume needed.

7.4.13. Proper protection shall be given to metal surfaces of pressure tanks
a. Tanks constructed of steel or other metal subject to corrosion shall have both interior and exterior surfaces painted.
   1. Exterior paint should contain less than 100 milligrams of lead per kilogram of dried paint to prevent removed paint from being classified as a hazardous waste.
   2. Interior paint shall be certified for drinking water use under the latest ANSI/NSF Standard 61.
b. Tanks constructed of corrosion resistant metals shall not be re[illegible] metals shall be chosen to[illegible]ng chemicals in the w[illegible] water treatment including chlorine and other disinfectants and the natural atmosphere including current and expected future air pollutants in the area.

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7.5. Fire Flow Information

7.5.1. Standard Fire Flow with Corresponding Fire Durations.

Standard fire flow with corresponding fire duration is indicated in the table here.

Table 5 - Design Needed Fire Flow

Design Needed Fire Flow (gallons per minute)	Fire Duration (hours)
250	2
500	2
750	2
1,000	2
1,250	2
1,500	2
1,750	2
2,000	2
2,250	2
2,500	2
3,000	3
3,500	3
4,000	4
4,500	4
5,000	4
5,500	4
6,000	4
6,500	4
7,000	4
7,500	4
8,000	4
8,500	4
9,000	4
9,500	4
10,000	4
	4
	4

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7.5.2. Fire Suppression Rating Schedule.

Public water supplies that provide fire protection should determine design needed fire flow and design supply works capacity in accordance with the latest Fire Suppression Rating Schedule published by Insurance Services Organization Inc. (ISO). Ideally, design supply works capacity should equal or exceed design needed fire flow.

7.5.3. Storage for Fire Flow

Storage for fire flow is only one of many components that must be assessed in the engineering design of public water supplies' fire suppression capability. Many other factors not related to water supply, including emergency communications capability, fire department capability, building code requirements, and zoning departments, influence fire suppression capability and ISO rating. All of these factors and local fire district requirements should be assessed in the engineering design for public water supply facilities that will support fire suppression. In general, public water supplies with populations greater than 250 persons and with service connection densities greater than 16 service connections per 160 acres should consider providing at least the levels of fire flow in the Table below.

Table 6 - Population and Fire Flow

Population	Fire Flow in Residential Areas	Fire Flow in Commercial Areas
250-999	250 gpm for 2 hours	250 gpm for 2 hours
1,000 to 9,999	1000 gpm for 2 hours	2,500 gpm for 2 hours
10,000 and greater	1,500 gpm for 2 hours	3,500 gpm for 3 hours